AN INVESTIGATION OF THE SHEAR STRESS DISTRIBUTION IN A SIMPLY SUPPORTED I-BEAM WITH A CONCENTRATED LOAD ACTING NEAR ONE END

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(Inter-Departmental)

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Office of
W. M. Murray
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September 25, 1946.

Captain W. H. Buracker,
Room 5-233

Thesis Work of LCDR C.C. WRIGHT, USN
LCDR J.A. LaSPADA, USN

Dear Captain Buracker:

In response to your request for information on the thesis work carried out by Lt. Comdr. C. C. Wright and Lt. Comdr. J. A. LaSpada it is a pleasure to tell you that I have been very favorably impressed with the work which they have done and that I am hoping to find someone else to carry on where they left off.

These gentlemen selected an interesting and important problem which they attached in a most thorough and businesslike manner. From the procedure which they adopted I am sure that they have gained valuable experience for themselves and at the same time I feel that they have produced results which will be of considerable value to other people interested in stresses in beams when conditions do not conform to the conditions and limitations of the beam theory.

In my opinion, the work of these two officers was of top notch caliber, and, in addition, it was a great pleasure to be associated with them in the capacity of thesis advisor.

Sincerely yours,

/s/ W. M. Murray

W. M. Murray

Cambridge, Massachusetts
September 16, 1946

Professor J. S. Newell
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Sir:

In accordance with the requirements for the degree of Master of Science in Naval Construction and Engineering, we submit herewith a thesis entitled "An Investigation of the Shear Stress Distribution in a Simply Supported I-Beam with a Concentrated Load Acting Near One End."

AN INVESTIGATION OF THE SHEAR STRESS DISTRIBUTION IN A SIMPLY SUPPORTED I-BEAM WITH A CONCENTRATED LOAD ACTING NEAR ONE END

By

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MASTER OF SCIENCE IN NAVAL CONSTRUCTION AND ENGINEERING

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1946

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The authors wish to express their appreciation and indebtedness to the following persons:

To Professor William M. Murray for his assistance and guidance in helping us select the approach to the problem.

To Mr. W. L. Walsh for his instruction in the use of strain gages, and for the use of his personal strain gage indicator.

To Mr. T. A. Newson for instructing us in the correct procedure for use and application of Stresscoat, for suggesting the use of his strain rosette nomograph, and for other helpful suggestions on the details of this thesis.

To Mr. E. L. Sinclair and Mr. A. F. Lynch of the Materials Section, Boston Naval Shipyard, for their prompt procurement of the necessary materials.

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TABLE OF SYMBOLS

A - Distance from load to near support, feet.

a - Auxiliary gage factor (no units).

B - Distance from load to far support, feet.

b - Thickness of beam at any position, inches.

C - Distance of point from neutral axis, inches.

E - Modulus of Elasticity, pounds per square inch.

I - Moment of inertia of section, $(\text{inches})^4$.

L - Length of beam span, feet.

M - Bending moment at section, foot-pounds.

Q - First moment of area outside of any line about the neutral axis, $(\text{inches})^3$.

V - Vertical shear, pounds.

W - Applied Load, pounds.

X - Horizontal distance from left support to any point, feet.

ε_1' - Strain in micro-inches per inch measured by strain rosette in the vertical direction.

ε_2' - Strain in micro-inches per inch measured by strain rosette in a direction equi distant from ε_1' and ε_3'.

ε_3' - Strain in micro-inches per inch measured by strain rosette in the horizontal direction.

ε_1 - Corrected value of strain in micro-inches per inch measured in the vertical direction

ε_2 - Corrected values of strain in micro-inches per inch measured equi distant from ε_1 and ε_3.

ε_3 - Corrected value of strain in micro-inches per inch measured in the horizontal direction.

ϕ - The angle measured counterclockwise from ε_3 to the direction of τ_m degrees.

σ_1 - Vertical Direct stress, pounds per square inch.

σ_3 - Longitudinal direct stress, pounds per square inch.

τ_m - Maximum shear stress, pounds per square inch.

τ_{31} - Shear stress in the 3-1 plane, pounds per square inch.

SUMMARY

I. OBJECT

The object of this thesis investigation was to determine the shear stress distribution in a simply supported I-beam with a concentrated load acting near one end.

II. PROCEDURE

An 8" x 4" x 6.6# aluminum I-beam was tested. This beam was supported 6 inches from one end; and by moving the supports, both length of span and position of load from near support were varied. Vertical static loads in increasing increments were applied in each position. (See figure V for photograph of the laboratory set up.)

One series of test runs was made to obtain data from Stresscoat crack patterns. A second series of runs was made to provide data from SR-4 strain gage measurements.

III. RESULTS

Plots of values of maximum shear stress at various points on the beam for each of four separate test runs are presented.

Strain gage data for the remainder of the strain gage test runs is included in Tables I to XVI.

Data obtained from each of the Stresscoat test runs, giving loading data and crack angles, are found in Tables XVII to XXXI.

SUMMARY

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The object of the thesis was attained in a practicable manner with good engineering accuracy.

The Stresscoat Method of Stress Analysis does not provide sufficient information to obtain quantitative values of shear stress, but does provide a good qualitative tensile strain picture of a loaded specimen.

RECOMMENDATIONS

This investigation should be continued for the entire series of I-beams in general use.

Further investigations should be made in such manner as to provide a maximum of data readings for each pattern of gages, to allow the graphical results expected to be easily faired.

I. INTRODUCTION

A. Concept of the Problem.

During World War II most structural investigations not directly related to winning the war were necessarily deferred. Among the investigations postponed by the Bureau of Ships, U.S. Navy, is the problem presented in this thesis: The Investigation of the Shear Stress Distribution in a simply supported I-Beam with a concentrated load acting near one end.

As stated by the Bureau of Ships in a letter to the authors, "The solution of this problem is of interest in the design of gun girders having a full web plate, in the design of many types of foundations for carrying concentrated loads, of flight deck longitudinals, and, in general, in all problems of transfer of load through shear in a beam. Ultimately, it is desired to make design recommendations in order to achieve greater economies when proportioning beams to resist shear."

Arbitrary limitations on this investigation, which is submitted as the first stages of a work which must certainly be continued to include the entire scope of this problem, were designated by the Bureau of Ships as being

1. The investigation of a flanged section, preferably a built-up or rolled "I" section.

2. The investigation of static conditions, in view of probable limitations imposed by laboratory facilities.

3. The study of the stress field produced under load in a flanged cross-section, rather than an investigation of methods of

reducing stress conditions.

B. Status of the Problem.

Preliminary search for published articles and texts relating to shear stress distribution in I-beam sections has resulted in the opinion by the authors, that no extensive tests to determine shear stress distributions in I-beams loaded other than at the center of the span have been undertaken.

In the preliminary analysis it was decided to limit the loading to values well below the elastic limit of the materials used, both to eliminate permanent deformation of the specimen during each test run and to obtain test conditions which would more nearly realize the loadings normally occurring in service.

The decision of the method of approach followed from examination of laboratory facilities available, which indicated that use of "Stresscoat" (Brittle Lacquer Method for Stress Analysis) would be valuable in searching for the general appearance of the stress field, at least the stress field formed by tensile and compressive stresses due to loading. Further, a transition from these general stress fields to specific quantitative shear stresses could be accomplished by solving for shear stresses from directional strains obtained from SR-4 type electric strain gages. The photo-elastic method of stress analysis was eliminated as an approach to our problem, for the present, on advice from the thesis supervisor, Professor Murray.

One factor which emerged from the preliminary analysis of the problem was the value of selecting a specimen which was a member of

a geometrically similar series; that is, which could be compared to either larger or smaller I-sections by ratios such as the ratio of depth of section to web thickness, or the ratio of depth of section to section modulus, etc. By this selection one of the variables present might be eliminated in the application of results of tests of one particular specimen to general practice. This process of selection was not employed. To reduce the project cost and to utilize surplus material, readily available, a single aluminum section was chosen arbitrarily with the following considerations:

1. The section depth was to be large enough to permit location of more than two rows of strain rosettes.

2. The length of section was to be short enough to provide a span well within the limits of the testing machine, yet great enough to allow the length of span to be introduced as a variable factor in the problem.

Presentation of results by graphical means (see pp 32 to 35) appeared to be of value, in that, since a standard U.S.Navy I-section was tested the results could be directly applied to that section. A mathematical formulation of shear stress distribution in a beam of the type investigated (from test data obtained) was deemed too lengthy a problem for the short period allotted by the curriculum to thesis. However, it is hoped that the data obtained in this investigation are extensive enough to allow future transposition into a mathematical solution of the problem.

A comparison of the observed and theoretical value of shear stresses (obtained from simple beam theory formulas) is made to illustrate the divergence of these values.

II. PROCEDURE

The essential steps followed in this investigation were as follows:

1. Selection of test specimen.

2. Selection of method of testing and means of obtaining data.

3. Determination of stress fields by use of Stresscoat, under varied conditions of span length and position of loading.

4. Determination of strains at specific points by means of strain gages, under varied conditions of span length and position of loading.

5. Calculation of value of maximum shear stress at each gage position from observed strain gage data.

6. Calculation of theoretical maximum shear stress at each strain gage location from simple beam formulas.

7. Comparison of observed and theoretical results.

For detailed discussion of description of equipment and method of testing see Appendix A.

III. [illegible]

1. Plots of values of maximum shear stress obtained from strain rosette data and values of maximum shear stress obtained from simple beam formulas and Mohr's circle vs. distance along the beam are shown on pages 32 to 35

2. Experimental Strain Gage Data are presented on pages 36 to 51

3. Stresscoat Crack Angle Data are summarized on pages 52 to 59 .

4. In the Stresscoat tests made in this investigation it was noted that the axis of vertical cracks in the lower half of the beam was in all cases displaced approximately one inch from the load position toward the center of the beam, irrespective of the beam span.

5. Superposition of the tension and compression Stresscoat crack contours showed that in most cases the intersections of the cracks obtained from the two different types of loading are perpendicular, as was expected.

6. Within the limits of the loads used, the angle of cracking at a given point in the Stresscoat crack pattern is independent of the load.

IV. DISCUSSION OF RESULTS

The results show that the shear stress distribution in a simply supported I-beam with a concentrated load acting near one end is not exactly that calculated from simple beam formulas and Mohr's Circle.

In general, the shear stress in the upper half of the web is greater than calculated values. In the lower half of the beam web the experimental and calculated shear stresses are in close agreement, except in the vicinity of the support, where an increase in shear stress is observed in all cases. In the upper half of the beam web the maximum value of shear stress does not occur at the position of loading, but the location of this maximum value is displaced towards the center of the span.

Not enough data has been worked up at present to determine accurately the effects of span length and position of load from near support on the ratio of observed maximum shear stress to calculated maximum shear stress.

It is believed that the Stresscoat Crack Angle Data presented above could be combined with calculated values of direct stresses to give a maximum shear stress for comparison with that obtained from strain gage data.

Since for a particular test run the crack contours appeared identical and independent of load, a single loading near, but safely below, the elastic limit, coupled with the increased sensitivity produced by a "cooling" agent, should be sufficient to delineate the direction of principal stresses. In this respect,

too many test runs were made to obtain Stresscoat data before the similarity between crack patterns appeared.

It is believed that the curves of results could have been faired more easily had a greater number of points been obtained by additional strain gage test runs.

The method of obtaining individual strain gage readings, that of using screw type binding posts to connect the test lead to the gage lead, though increasing the time necessary for each run, appears to give more accurate readings and simplifies the procedure of isolating any individual defective gage found.

In order to reduce one of the possible experimental errors, observed strain gage readings were faired to obtain values used in calculations. In some cases a greater number of observations would have permitted more accurate fairing. To allow presentation of similar curves for each test run, faired values corresponding to the same arbitrary loads were used for calculation in all cases.

The effect of reducing strains to even numbers is considered as negligible, since the load scale of the testing machine provided accuracy only to within 5 pounds.

The results are not as extensive as desired by the authors. However, it is believed that the results shown are representative of the shear stress distribution in an I-beam web under the conditions of loading selected for this investigation.

V. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. The object of the thesis is considered accomplished.

2. The method used to obtain shear stress is practicable, and the nomograph solution provides engineering accuracy with saving of time.

3. Stresscoat runs revealed the following considerations.

a. Use of Stresscoat is advantageous in cases where an overall strain picture is desired. This would be particularly valuable in examinations of a complicated structure which could not be isolated or of which a model could not be built without excessive cost.

b. The use of CO_2 as a "cooling" agent is extremely useful, although matching observed and calibrated strains is not practicable under the cooled conditions.

4. A check on the accuracy of Stresscoat contours can be made by super position of the tensile crack pattern and the compression crack pattern.

RECOMMENDATIONS

The authors recommend the following:

1. That this investigation be continued and enlarged to include tests of I-beams other than the 8" x 4" x 6.8" aluminum I-beam already tested, and that the results be coordinated to determine relations between observed test results on one material and anticipated results in another metal and to determine the influence of varying dimensions on shear stress distribution.

2. That in other investigations of this type, where application of Stresscoat tests is contemplated, the greater proportion of available time be spent in quantitative strain gage tests rather than in qualitative Stresscoat testing.

3. That in any continuance of this investigation the beam be tested in such manner as to provide data at shorter intervals than one reading for each six inches of beam length in each row of gages, and where practicable more rows of gages be introduced.

VI- APPENDIX

APPENDIX A

Details of Test Beams

A. Description of Aluminum

1. Beam

The aluminum I-section tested was an 8" x 4" x 6.6# rolled beam eight feet in length. The properties of this material (as determined from Section 3A13d, Navy Department Specifications, are as follows:

Physical:

Tensile Strength	22,000 lbs/sq in. (maximum)
Elongation	16%

Chemical:

Magnesium	0.8 - 1.2%
Silicon	0.4 - 0.8%
Copper	0.15 - 0.4%
Iron	0.7% (maximum)
Chromium	0.15 - 0.35%
Zinc	0.10% (maximum)
Titanium	0.15 (maximum)
Manganese	0.15% (maximum)
Other elements	0.15% (maximum)
Aluminum	Remainder

The test section was reannealed by the following heat treatment:

1. Heat from room temperature to 850°F at rate of 50° per hour.

2. Bake at 850° for 2 hours.

3. Cool from 850° to room temperature at rate of 25° per hour. This section was selected for the following reasons:

1. It was dimensionally identical with the 8" x 4" x 18.4# steel I-section that is in general use in the U.S. Navy.

2. Its relatively light weight provided for ease in handling.

3. The externally applied loads required to produce reasonable deflections were well within the capacity of any testing apparatus normally used in laboratory examination.

4. The surface scale formation usually present was easily removed to provide the smooth surface prerequisite to even distribution of Stresscoat lacquer and necessary to establish a close bonding between strain gages and the metal.

2. TESTING MACHINE

The testing machine used in all test runs was the Riehle Universal Testing Machine, having a maximum capacity of 100,000 pounds. (See Figures IV and V.)

3. MEASURING DEVICES

2. STRESSCOAT

This material is manufactured by the Stresscoat Division, Magnaflux Corporation. Its application and interpretation followed,

basically, the principles set forth in the Stresscoat "Manual of Operating Instructions".

b. STRAIN GAGES, ETC.

The measuring gages were standard types of SR-4 Bonded Resistance Wire Strain Gages, of types illustrated in Figures I and II, manufactured by Baldwin Southwark Division, Baldwin Locomotive Works. Both single gages of types A-1 and A-5, and rectangular strain rosettes of type AR-1, were used. The single gages were located on the beam flanges where unidirectional stresses were expected. The strain rosettes were bonded to the beam web.

c. NOMOGRAPHS

As a means of reducing time of solution for shear stress from strain rosette data, the nomograph (See Figure III), developed by Mr. T. A. Howson of the Division of Industrial Cooperation, M.I.T., was a very valuable aid. A comparison of accuracy of nomograph solutions and calculated solutions showed a difference of from 0.4% to 5% in over 100 cases.

B. DESCRIPTION OF TESTS

1. METHOD OF LOADING

The beam was subjected to various static loadings in the testing machine. There were no dynamic load tests due both to preliminary arbitrary limitations placed on the investigation and to lack of available facilities in the Materials Testing Laboratory. The arrangement of movable supports of the testing machine (see Figures IV and V) allowed for variation in length of

beam span and variation in distance between point of application of load and point of support, independent of each other. The supports and loading wedge were faced with one inch diameter half-round, transverse steel bars which provided support and loading, respectively, across the entire width of flange and of a length of not more than $\frac{1}{8}$ of an inch. (See Figure II). It was considered, therefore, that these members were "knife edges", providing line, rigid support.

2. STRESSCOAT TESTS

Stresscoat tests were made for informative reasons, to determine the appearance of the tensile and compressive strain fields under loading. (A typical Stresscoat pattern for a 3" x 2 3/8" x 2.0# aluminum I-beam is illustrated in Figures VI and VII). The load position and length of span were varied in some of these test runs. Since Stresscoat reacts both to tensile loading, and to compressive loading under certain conditions, some runs were made for each of these two types of loads. The compression load strain patterns were compared with the tensile strain patterns. No effort was made to match observed and calibrated strains. In the cases where strain patterns were matched wide divergence of results was noted. It is not known whether this divergence was due to inability of the authors to correctly match strains or to variation in the sensitivity of the beam patterns and those on the calibration strips. To obtain greatly enlarged areas of strain patterns, the beam surfaces were cooled suddenly

by means of blasts of compressed gaseous carbon dioxide expanding against the metal surfaces. This cooling process has great advantage in a qualitative testing. Greatly increased strain sensitivity of Stresscoat at low temperatures allows a much more complete strain picture, providing the aid of the overall pattern of the entire specimen wherever strains are present. In the test runs of this thesis, for instance, cooling the web surfaces provides strain patterns on the compression side of the neutral axis of the beam. No attempt was made to determine the lacquer sensitivity under the "cooled" conditions.

3. STRAIN GAGE TESTS

The method of loading applied to obtain data for computation of shear stress is described in paragraph B (1), above. Readings of each strain gage's resistance were taken by means of the SR-4 Strain Indicator (See Figure VIII) at each load in each test run. That is, for each run a load was applied and the strain readings were taken; the load was increased and readings were again taken; and so on. The readings taken at approximately 500 pounds load were used as check readings since it was found that readings for zero load could not be compared with any accuracy.

FIGURE I. Location of Strain Gages H-1, H-2, H-3 and H-4 on Bottom of Lower Flange. Note Gages D-1 and D-2 on Under Side of Upper Flange.

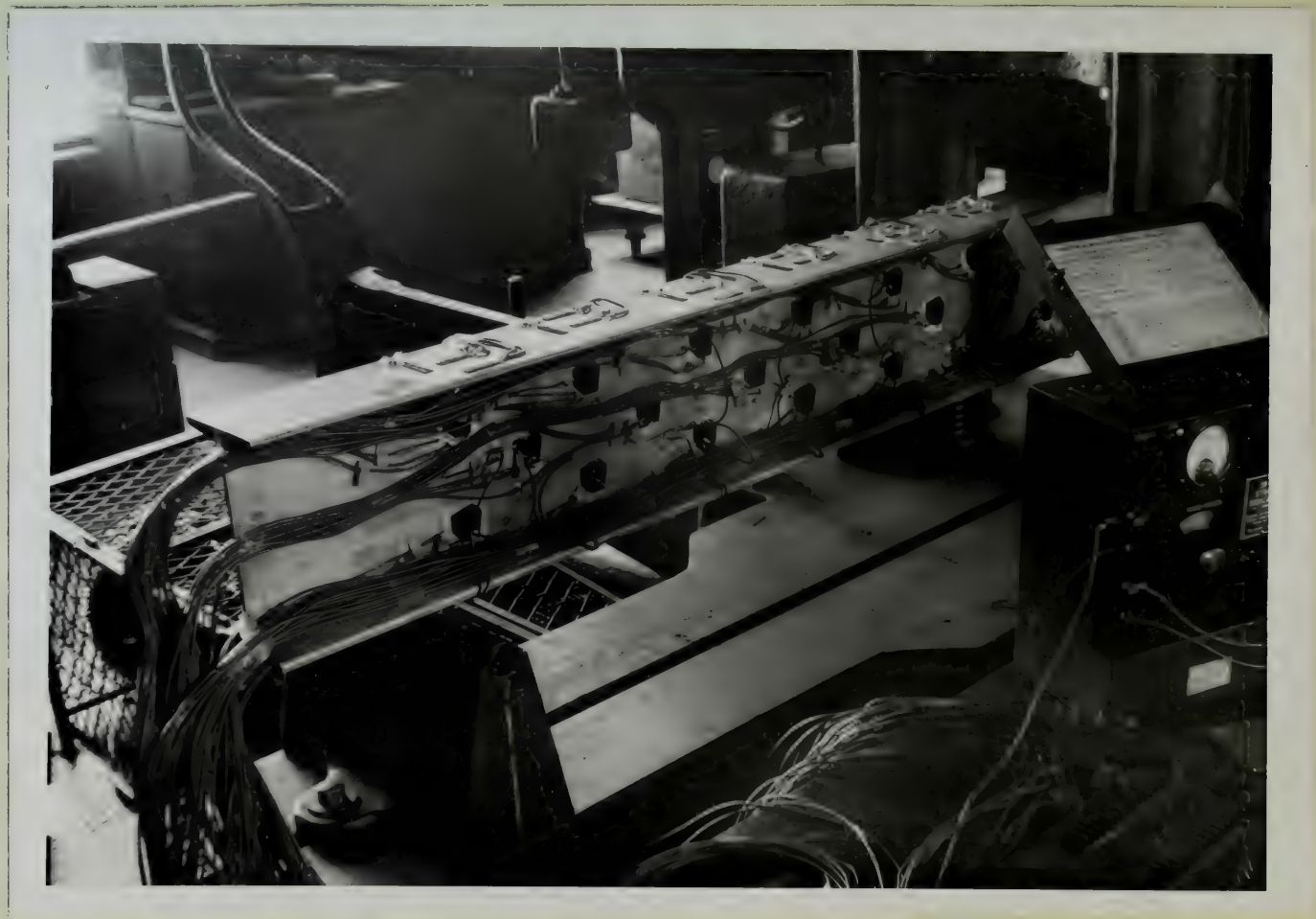
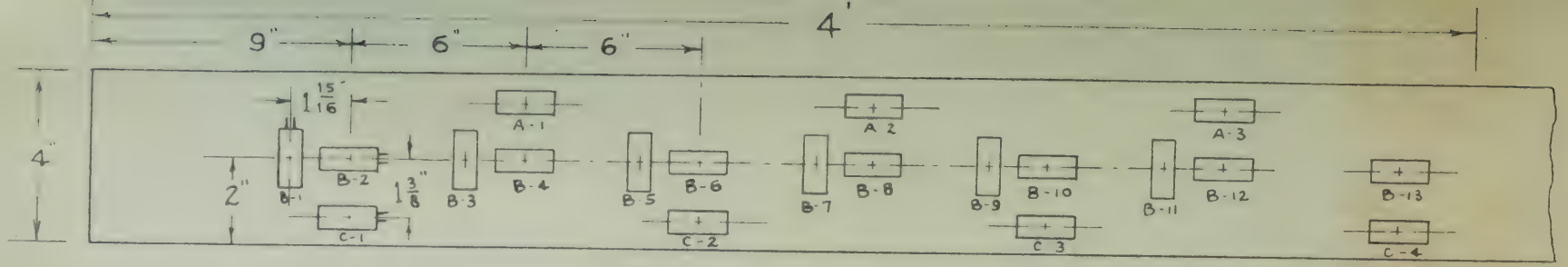
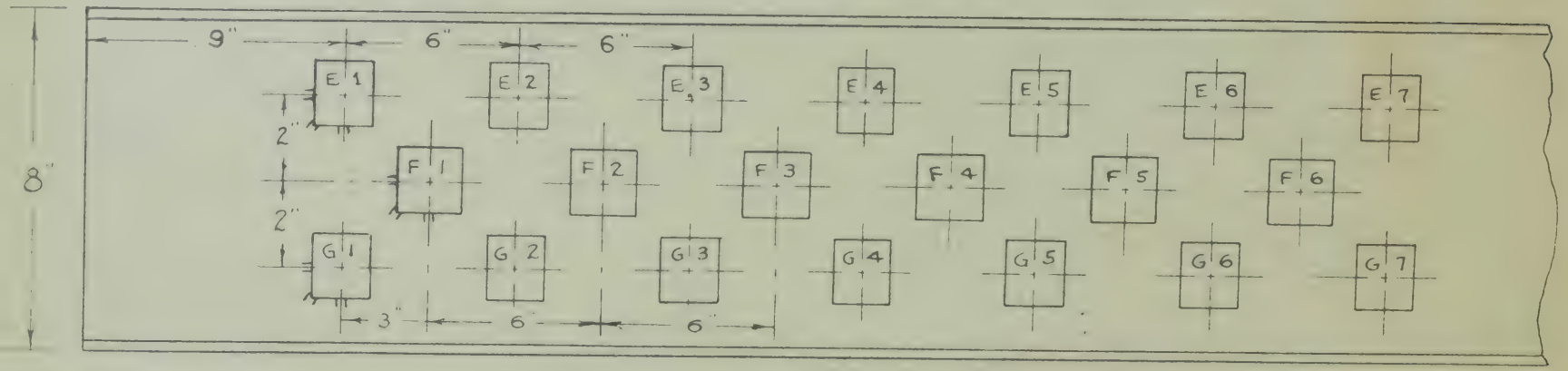


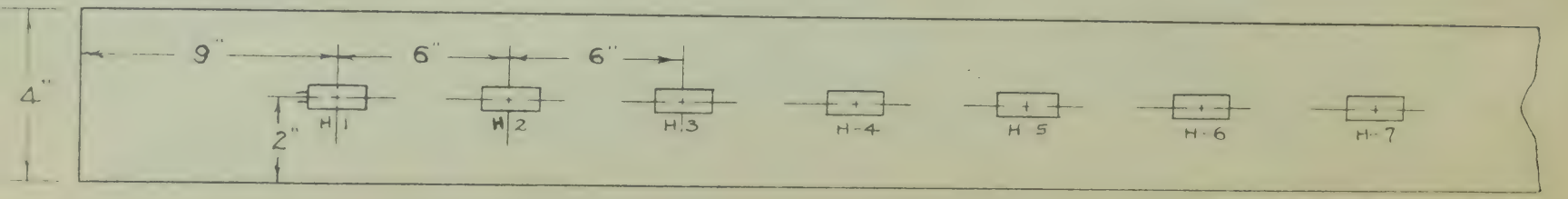
FIGURE II. (a) Location of Strain Rosettes (Rows, B, F, and G) on Flange Web, and Single Strain Gages (Rows A, E, and C) on Top of Upper Flange.



TOP OF TOP FLANGE



WEB



BOTTOM OF BOTTOM FLANGE

FIGURE II (B). LOCATIONS OF SR-4 STRAIN GAGES.

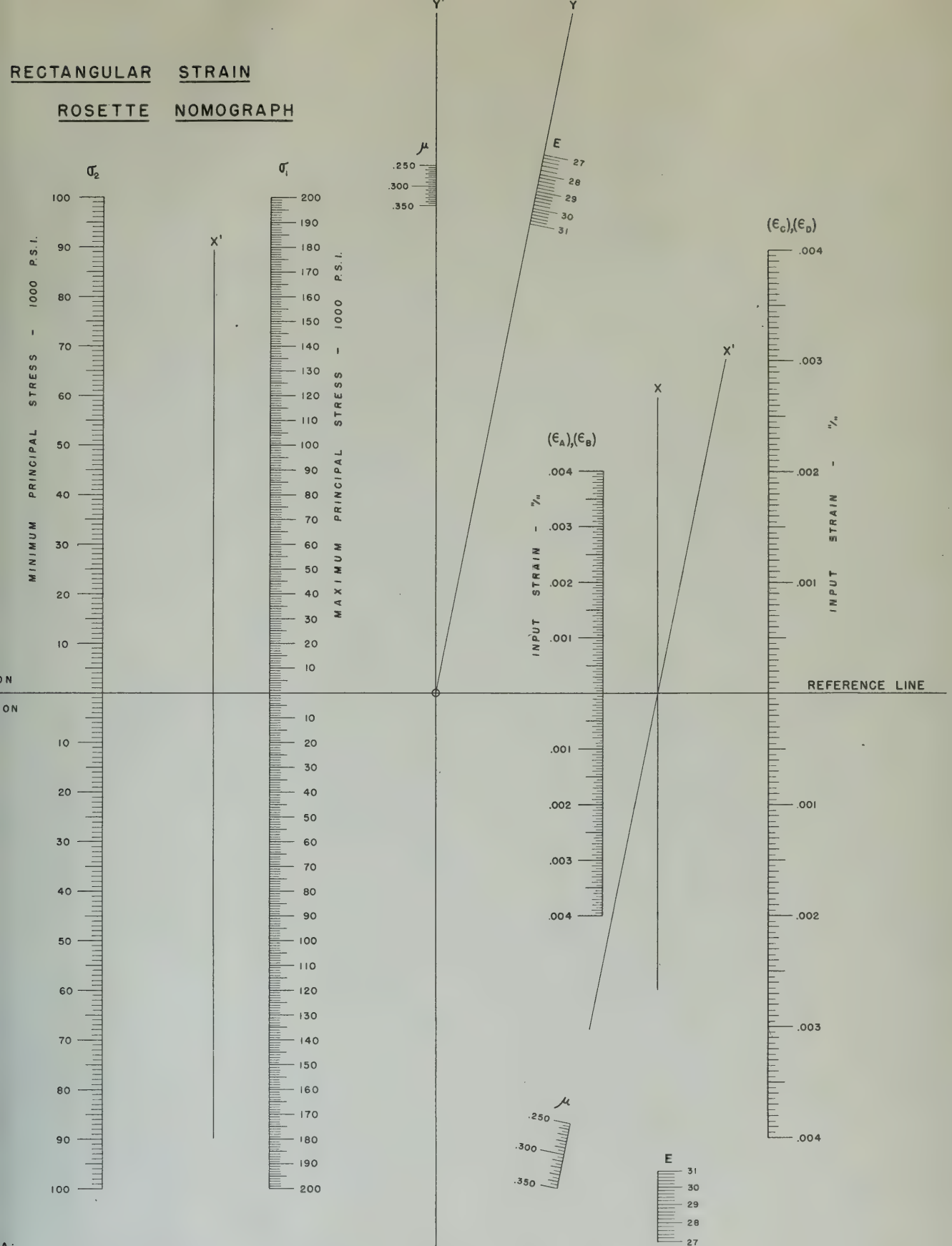


Figure III. Sample Nomograph used for solution of Sheer Stress from Strain Gage Data.

FIGURE IV. Riehle Universal Testing Machine with Beam in Position for Loading. Arrows Show Locations of Supports and Loading Wedge.

FIGURE V. General View of Test Arrangement.

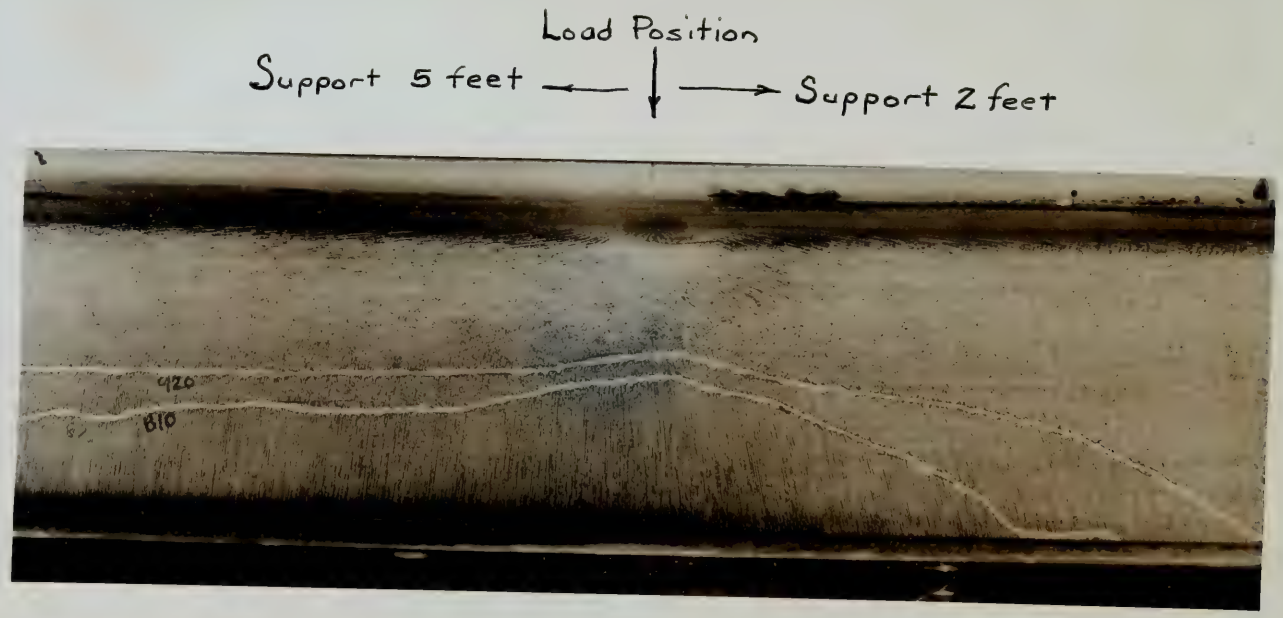


FIGURE VI. Typical Stresscoat Crack Pattern.
Beam shown is 3" x 2 3/8" Aluminum I-Beam.
Heavy scratch lines indicate extent of crack pattern for the load noted. Remainder of crack pattern obtained by use of CO_2 to cool web surface.

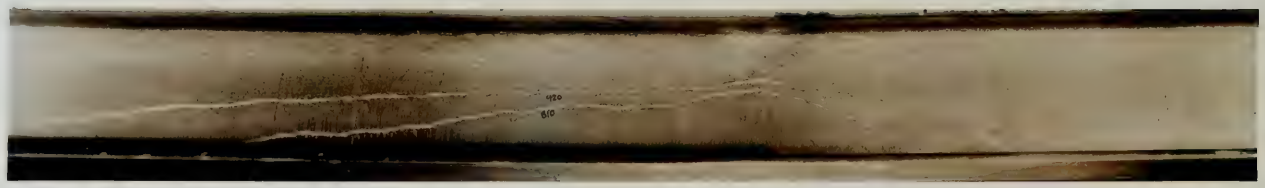
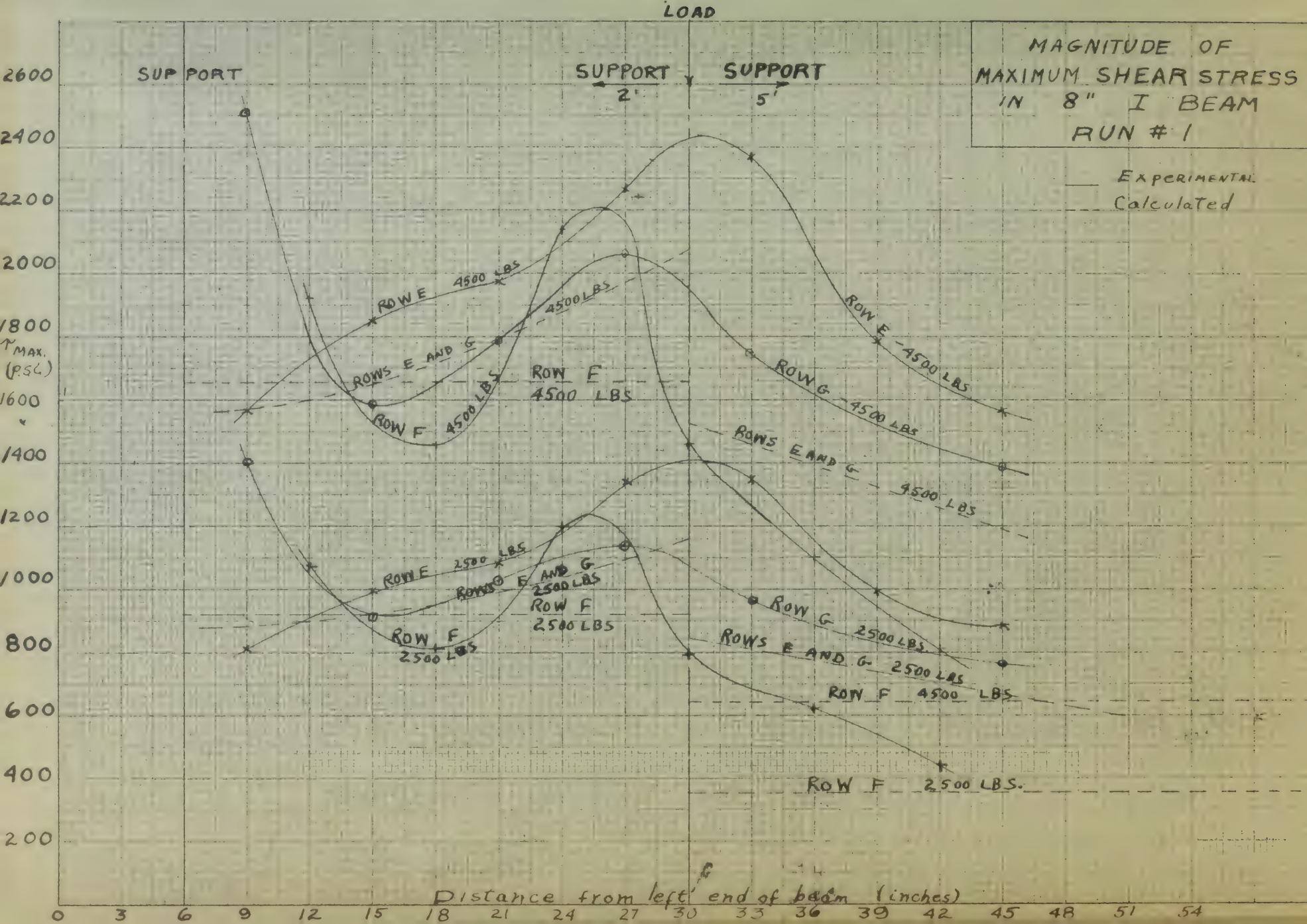


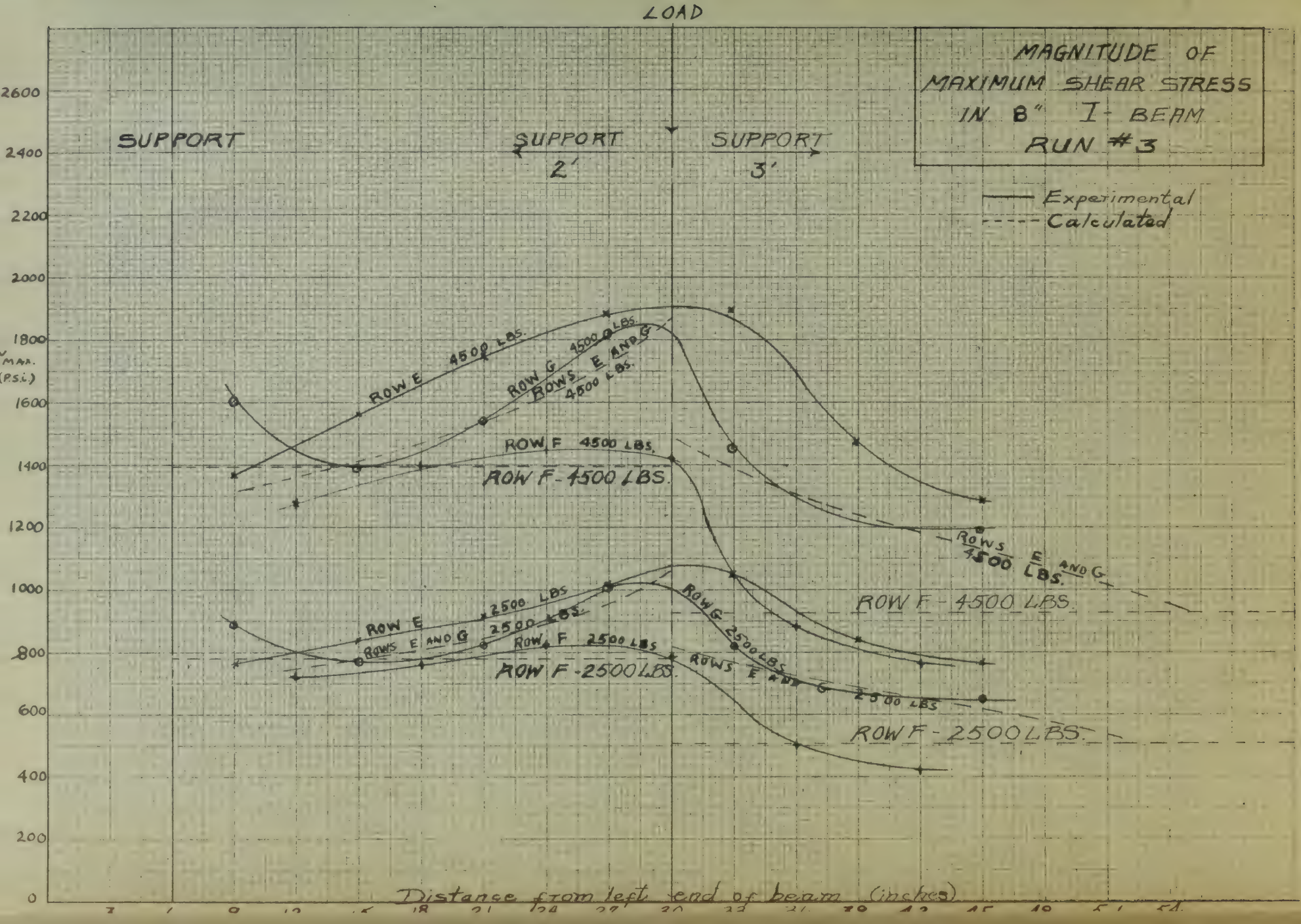
Figure VII. 3" Aluminum Beam with Typical Stresscoat Crack Pattern. This is same beam as in Fig. VI, but a greater length of beam is shown.

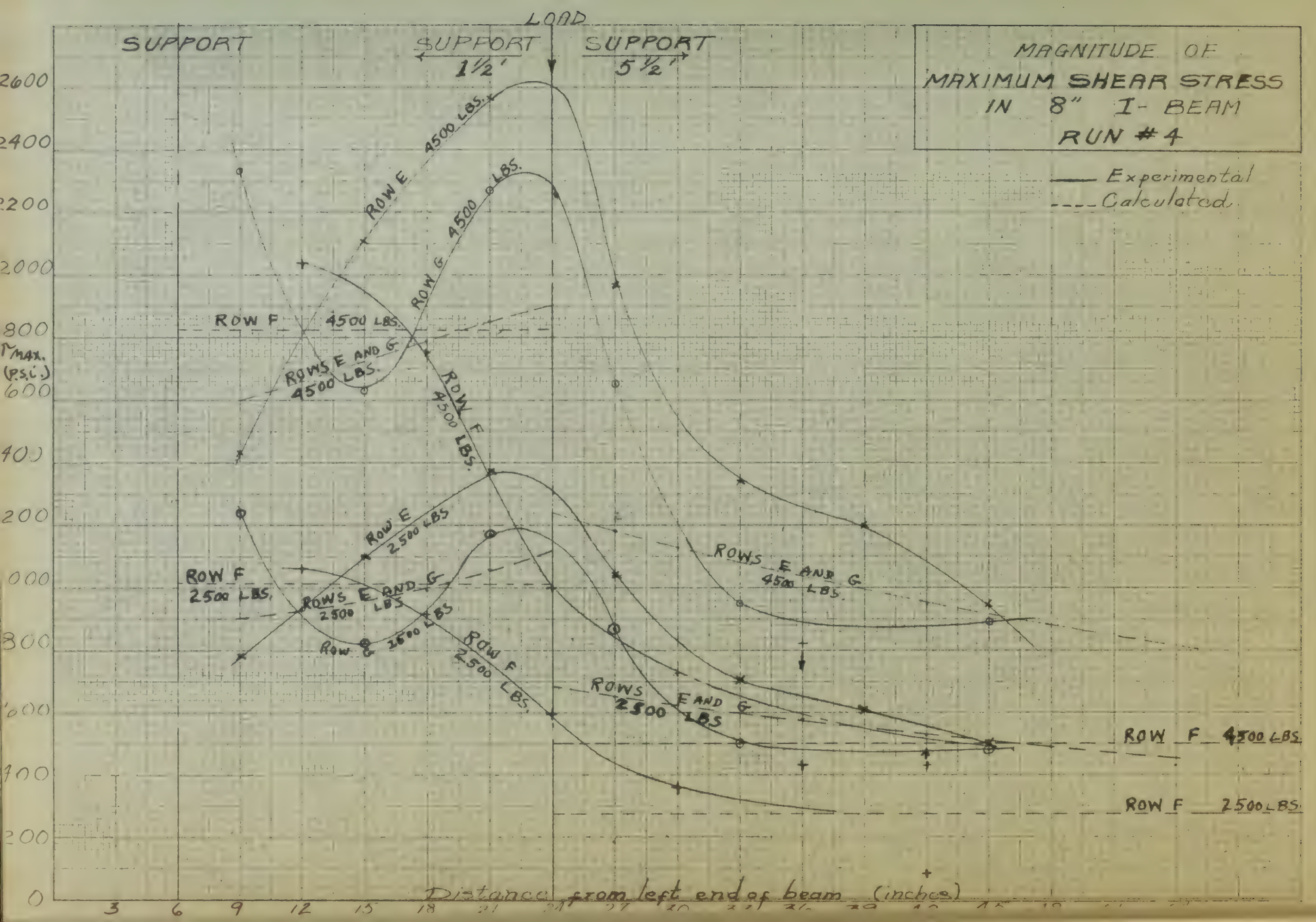
FIGURE VIII. Baldwin Southwark SR-4 Strain Indicator used in Beam Tests. Compensating Gage shown in foreground. Note connector strips beside indicator. Binding posts were used to assure positive connection by crushing lead to indicator against lead to individual Gages.

APPENDIX I.

TABLE OF MYTULUS


LOAD
SUPPORT
SUPPORT
2'
SUPPORT
5'
MAGNITUDE OF MAXIMUM SHEAR STRESS IN 8" I BEAM RUN # 1
EXPERIMENTAL
Calculated
2600
2400
2200
2000
1800
τ MAX. (PSI)
1600
1400
1200
1000
800
600
400
200
ROW E 4500 LBS
ROWS E AND G 4500 LBS
ROW F 4500 LBS
ROW F 4500 LBS
ROW E 4500 LBS
ROW G 4500 LBS
ROWS E AND G 4500 LBS
ROW E 2500 LBS
ROWS E AND G 2500 LBS
ROW F 2500 LBS
ROW F 2500 LBS
ROW G 2500 LBS
ROWS E AND G 2500 LBS
ROW F 4500 LBS
ROW F 2500 LBS.
Distance from left end of beam (inches)
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54


LOAD
MAGNITUDE OF MAXIMUM SHEAR STRESS IN 8" I-BEAM RUN #3
Experimental
Calculated
SUPPORT
SUPPORT 2'
SUPPORT 3'
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
V MAX. (P.S.I.)
ROW E 4500 LBS.
ROW G 4500 LBS.
ROWS E AND G 4500 LBS.
ROW F 4500 LBS.
ROW F - 4500 LBS.
ROWS E AND G 4500 LBS.
ROW F - 4500 LBS.
ROW E 2500 LBS.
ROWS E AND G 2500 LBS.
ROW F 2500 LBS.
ROW F - 2500 LBS.
ROW G 2500 LBS.
ROWS E AND G 2500 LBS.
ROW F - 2500 LBS.
Distance from left end of beam (inches)


LOAD
SUPPORT
SUPPORT
1½'
SUPPORT
5½'
MAGNITUDE OF
MAXIMUM SHEAR STRESS
IN 8" I-BEAM
RUN #4
Experimental
Calculated
ROW E 4500 LBS.
ROW G 4500 LBS.
ROW F 4500 LBS.
ROWS E AND G
4500 LBS.
ROW F
4500 LBS.
ROW E
2500 LBS
ROW F
2500 LBS.
ROWS E AND G
2500 LBS
ROW G 2500 LBS
ROWS E AND G
4500 LBS.
ROWS E AND G
2500 LBS
ROW F 4500 LBS.
ROW F 2500 LBS.
τMAX. (P.S.I.)
2600
2400
2200
2000
800
600
400
200
000
800
600
400
200
0
3
6
9
12
15
18
Distance from left end of beam (inches)

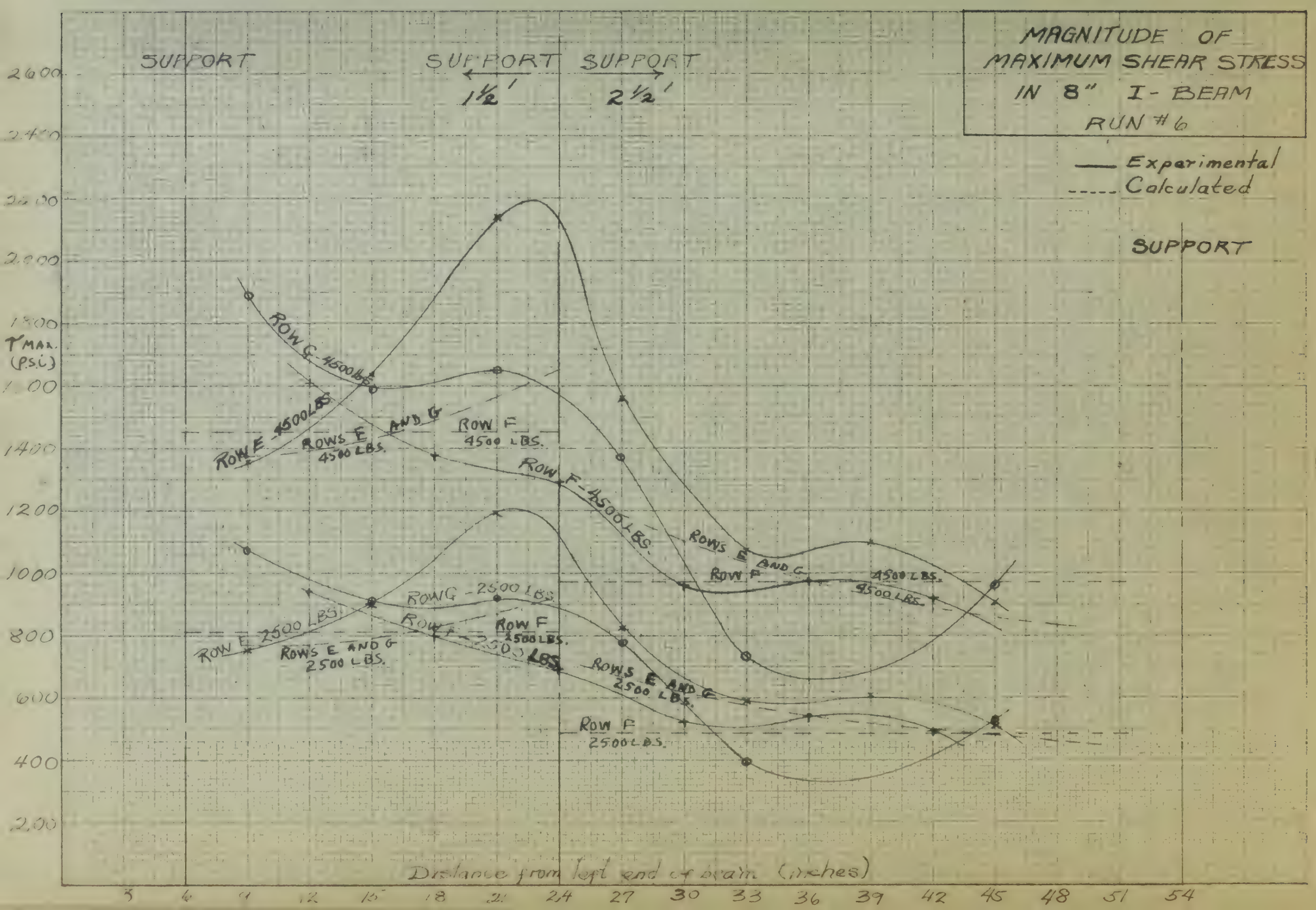

MAGNITUDE OF MAXIMUM SHEAR STRESS IN 8" I-BEAM RUN #6
Experimental
Calculated
SUPPORT
SUPPORT
SUPPORT
1½'
2½'
SUPPORT
T MAX. (P.S.I.)
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
ROW G - 4500 LBS.
ROW E - 4500 LBS.
ROWS E AND G 4500 LBS.
ROW F 4500 LBS.
ROW F - 4500 LBS.
ROWS E AND G 4500 LBS.
ROW F 4500 LBS.
4500 LBS.
ROW G - 2500 LBS.
ROW E - 2500 LBS.
ROWS E AND G 2500 LBS.
ROW F 2500 LBS.
ROWS E AND G 2500 LBS.
ROW F 2500 LBS.
Distance from left end of beam (inches)
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54

TABLE 1.

CALCULATED STRAIN GAGE DATA

Run Number: 1 17 August 1946

Beam Span 7 feet Load Position 2 feet from near support

Load 2500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3	γ_m	ϕ
E-1	-18	-112	-23	-18	-113	-23	-816	44
E-2	3	-135	-67	4	-137	-67	-1000	35½
E-3	1	-152	-73	2	-154	-73	-1080	34½
E-4	-17	-212	-187	-13	-212	-187	-1342	25½
E-5	175	-21	-176	119	-20	-178	-1350	1½
E-6	34	0	-146	37	+2	-147	988	-15½
E-7	18	12	-123	21	14	-123	-882	
F-1	-11	-128	-8	-11	-151	-8	1078	45
F-2	-123	1	0	-123	3	-2	810	24¼
F-3	-28	-138	15	-28	-140	16	-1200	-40½
F-4	-142	-98	+21	-142	-97	24	-794	-12½
F-5	-29	41	-26	-28	43	-25	620	45½
F-6	-16	33	-11	-18	35	-11	446	43½
G-1	-12	-159	0	-12	-162	0	-1400	-44
G-2	-27	-81	45	-28	-83	46	904	-34½
G-3	-38	-88	65	-30	-91	66	-1034	-32
G-4	-66	-64	115	-68	-66	116	-1136	-22½
G-5	-62	86	100	-64	87	101	960	20
G-6	115		-42	116		-44		
G-7	-50	66	92	-52	66	93	760	16½

TABLE II.

CALCULATED STRAIN GAGE DATA

Run Number: 1 17 August, 1946

Beam Span 7 feet Load Position 2 feet from near support

Load 3500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3
E-1	-25	-159	-32	-24	-161	-31
E-2	5	-188	-93	7	-190	-93
E-3	2	-213	-103	4	-215	-103
E-4	-22	-297	-261	-17	-297	-261
E-5	160	-29	-248	165	-28	-251
E-6	51	0	-202	55	3	-203
E-7	25	17	-173	29	20	-174
F-1	-15	-180	-11	-15	-183	-11
F-2	-172	1	0	-172	4	3
F-3	-40	-191	24	-40	-195	25
F-4	-200	-136	+29	-201	-135	33
F-5	-36	59	-56	-37	62	-35
F-6	-25	50	-14	-25	52	-13
G-1	-15	-223	0	-15	-228	0
G-2	-38	-114	63	-39	-117	64
G-3	-56	-121	90	-58	-124	91
G-4	-90	-88	161	-93	-92	163
G-5	-85	120	138	-88	121	140
G-6	160		-60	181		-63
G-7	-69	94	129	-72	95	130

TABLE III.

CALCULATED STRAIN GAGE DATA

Run Number: 1 17 August 1946

Beam Span 7 feet Load Position 2 feet from near support

Load 4500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3	τ_m	ϕ
E-1	-32	-204	-43	-31	-206	-42	1566	-44 1/8
E-2	6	-243	-121	8	-246	-121	1850	-35 1/16
E-3	3	-275	-133	6	-275	-133	1978	35½
E-4	-30	-382	-337	-23	-383	-336	2272	26
E-5	207	-37	-314	214	-36	-316	2376	-1¾
E-6	64	0	-259	70	4	-260	1786	-15½
E-7	31	21	-220	36	25	-221	1504	-21¼
F-1	-20	-232	-13	-20	-236	-13	1920	-44½
F-2	-222	2	0	-222	6	4	1586	23
F-3	-51	-249	29	-52	-254	30	2140	-40½
F-4	-258	-176	37	-259	-175	42	1460	-13 3/8
F-5	-49	74	-46	-48	77	-45	1100	44¾
F-6	-32	63	-21	-32	65	-20	814	42 5/8
G-1	-23	-286	0	-23	-292	0	2510	-44
G-2	-49	-145	82	-51	-147	83	1588	-34
G-3	-68	-157	117	-66	-156	118	1784	-51¼
G-4	-118	-115	208	-122	-119	211	2062	-21¼
G-5	-112	153	179	-116	155	181	1742	19¾
G-6	205		-79	207		-83		
G-7	-89	116	166	-93	116	168	1384	16

TABLE IV.

CALCULATED STRAIN GAGE DATA

Run Number: 1 17 August 1948

Beam Span 7 feet Load Position 2 feet from near support

	Load(Pounds)		
	2500	3500	4500
A-1	-115	-163	-207
A-2	-396	-553	-604
A-3	-254	-358	-458
B-1	9	12	15
B-2	-25	-35	-47
B-3	19	26	35
B-4	-113	-159	-203
B-5	45	63	80
B-6	-88	-138	-205
B-7	62	88	111
B-8	-203	-284	-368
B-9	218	305	397
B-10	-249	-345	-442
B-11	73	102	132
B-12	-254	-356	-459
B-13	-168	-255	-345
C-1	-36	-50	-65
C-2	-226	-315	-398
C-3	-404	-554	-724
C-4	-173	-241	-308
D-1	-26	-37	-47
D-2	-135	-190	-245
H-1	54	78	101
H-2	91	128	166
H-3	148	207	268
H-4	372	382	491
H-5	295	391	514
H-6	372	382	491
H-7	214	301	385

TABLE V.

CALCULATED STRAIN GAGE DATA

Run Number: 3 19 August 1946

Beam Span 5 feet Load Position 2 feet near support

Load 2500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3	τ_m	ϕ
E-1	-57	-134	-50	-56	-132	-49	-770	-40
E-2	-19	-135	-70	-18	-133	-81	-840	35
E-3	0	-133	-81	0	-136	-81	-940	33 1/4
E-4	-47	-202	-164	-44	-198	-163	-1006	28 3/4
E-5	-7	-7	-169	-3	-3	-169	1060	-23
E-6	0	-13	-139	3	-10	-139	854	-20
E-7	0	0	-108	2	2	-108	694	-22
F-1	-17	-139	-70	-16	-137	-70	-870	36 3/4
F-2	-149	-30	-29	-148	-26	-26	-760	22 1/2
F-3	-29	-136	-60	-28	-134	-58	-838	40 1/4
F-4	-131	-90	25	-132	-88	28	-786	-12
F-5	-20	26	-37	-19	27.5	-37	500	-40
F-6	-26	25	-15	-26	26	-14	420	41 1/2
G-1	-17	-121	-27	-16	-120	-27	-902	43 1/4
G-2	-16	-101	-18	-16	-100	-18	-748	44 1/2
G-3	-53	-101	20	-53	-100	21	-832	-32 3/4
G-4	-84	-96	68	-85	-98	70	-1016	-25
G-5	-74	50	75	-78	50	77	820	16 1/4
G-6	50		-101	52		-102		
G-7	-45	53	20	-45	54	21	654	38

TABLE VI.
CALCULATED STRAIN GAGE DATA

Run Number: 3 19 August 1946

Beam Span 5 feet Load Position 2 feet from near support

Load 3500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3
E-1	-81	-188	-69	-80	-185	-67
E-2	-32	-217	-129	-29	-214	-128
E-3	-0	-168	-115			
E-4	-67	-284	-231	-62	-278	-230
E-5	-0	-9	-238	-4	-4	-238
E-6	0	-18	-194	4	-14	-194
E-7	0	0	-151	3	3	-151
F-1	-24	-194	-99	-22	-192	-99
F-2	-208	-42	-41	-207	-37	-37
F-3	-42	-188	-85	-40	-185	-84
F-4	-185	-126	35	-186	-123	39
F-5	-20	55	-50	-27	154	-49
F-6	-38	55	-20	-38	36	-19
G-1	-23	-169	-38	-22	-168	-38
G-2	-23	-141	-24	-23	-140	-24
G-3	-75	-144	26	-76	-143	28
G-4	-116	-134	95	-118	-134	97
G-5	-104	66	105	-106	66	107
G-6	70		-142	73		-143
G-7	-65	73	30	-66	74	31

TABLE VII.
CALCULATED STRAIN GAGE DATA

Run Number: 5 19 August 1946

Beam Span 5 feet Load Position 2 feet from near support

Load 4500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3	τ_m	ϕ
E-1	-104	-242	-89	-102	-243	-87	-1370	-40
E-2	-38	-279	-130	-36	-281	-129	-1580	35
E-3	0	-240	-148	3	-242	-148	-1640	33¾
E-4	-83	-366	-297	-77	-365	-295	-1876	29¼
E-5	-11	-15	-305	-5	-8	-305	1890	-22
E-6	0	-24	-249	5	-19	-249	1486	-20
E-7	0	0	-193	4	4	-193	1274	-22½
F-1	-82	-251	-127	-29	-253	-126	-1610	-37
F-2	-270	-55	-53	-269	-50	-48	1586	22½
F-3	-55	-239	-110	-53	-241	-109	-1442	40
F-4	-237	-163	43	-238	-162	48	-1420	-12½
F-5	-36	46	-67	-35	49	-66	880	-40¼
F-6	-49	45	-27	-48	48	-26	770	41¼
G-1	-30	-217	-49	-29	-219	-48	-1600	43½
G-2	-30	-182	-50	-29	-184	-29	-1380	45
G-3	-95	-185	34	-96	-187	36	-1526	-58¾
G-4	-150	-173	122	-153	-175	125	-1816	-25
G-5	-134	86	132	-137	88	135	1454	17
G-6	90		-183	94		-185		
G-7	-80	95	87	-81	98	89	1190	32

TABLE VIII.

CALCULATED STRAIN GAGE DATA

Run Number: 3 — 19 August 1946

Beam Span 5 feet — Load Position 2 feet from near support

	Load (pounds)		
	2500	3500	4500
A-1	-118	-166	-213
A-2	-182	-256	-329
A-3	-230	-322	-414
B-1	-29	-39	-50
B-2	-66	-95	-122
B-3	-25	-35	-45
B-4	-129	-180	-231
B-5	-4	-6	-9
B-6	-169	-235	-304
B-7	11	16	20
B-8	-214	-301	-389
B-9	91	128	164
B-10	-236	-331	-426
B-11	11	16	20
B-12	-297	-419	-540
B-13	-194	-274	-352
C-1	-75	-106	-136
C-2	-213	-299	-384
C-3	-214	-301	-389
C-4	-136	-217	-280
D-1	-72	-102	-131
D-2	-183	-257	-330
H-1	0	0	0
H-2	44	61	79
H-3	82	114	147
H-4	183	257	330
H-5	210	294	380
H-6	144	200	257
H-7	87	121	155

TABLE IX.

CALCULATED STRAIN GAGE DATA

Run Number: 4 — 23 August 1946

Beam Span 7 feet — Load Position 1½ feet from near support

Load 2500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3	τ_m	ϕ
E-1	-35	-117	-27	-34	-116	-26	-780	-43½
E-2	-5	-153	-55	-4	-152	-55	-1100	39
E-3	0	-217	-176	4	-213	-176	-1380	27
E-4	14	-32	-185	18	-29	-185	1038	-13½
E-5	23	-9	-113	25	-7	-113	702	-13¾
E-6	22	-2	-94	25	1	-94	612	-15½
E-7	10	0	-76	12	1	-76	500	-18½
F-1	-10	-134	-19	-10	-133	-19	-1064	43
F-2	-142	0	-14	-142	3	-11	918	26
F-3	-134	-78	-15	-134	-75	-2	-596	-2½
F-4	0	20	-32	1	21	-32	360	-32½
F-5	-26	21	-28	-28	22	-27	432	45
F-6	-4	7	0	-4	7	0	91	39¾
G-1	-23	-147	6	-23	-147	6	-1240	-41½
G-2	-14	-58	65	-15	-59	63	-822	-32½
G-3	-51	-114	62	-52	-114	63	-1176	-32
G-4	-80	45	95	-82	45	97	868	11
G-5	-31	43	69	-32	42	70	500	12
G-6	85		-31	86		-33		
G-7	-21	52	70	-22	51	70	482	15½

TABLE X.
CALCULATED STRAIN GAGE DATA

Run Number: 4 — 23 August 1946

Beam Span 7 feet — Load Position 1½ feet from near support

Load 3500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3
E-1	-52	-168	-40	-51	-167	-39
E-2	-7	-221	-79	-5	-219	-79
E-3	0	-315	-254	5	-310	-254
E-4	20	-47	-269	25	-113	-269
E-5	32	-14	-163	35	-11	-164
E-6	31	-2	-136	34	0	-137
E-7	15	0	-110	17	2	-110
F-1	-16	-193	-27	-15	-193	-27
F-2	-205	0	-18	-205	4	-14
F-3	-194	-114	-22	-194	-110	-18
F-4	0	27	-47	1	28	-47
F-5	-42	30	-40	-41	32	-39
F-6	-5	9	0	-5	9	0
G-1	-33	-214	8	-35	-215	8
G-2	-20	-83	95	-22	-85	95
G-3	-74	-167	89	-76	-167	90
G-4	-115	86	139	-118	86	141
G-5	-44	64	96	-46	62	99
G-6	123		-44	124		-47
G-7	-30	73	100	-32	71	101

TABLE XI.
CALCULATED STRAIN GAGE DATA

Run Number: 4 — 23 August 1946

Beam Span 7 feet — Load Position 1½ feet from near support

Load 4500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3	τ_m	ϕ
E-1	-68	-223	-52	-67	-221	-51	-1436	46¾
E-2	-8	-289	-105	-6	-287	-103	2114	59
E-3	0	-410	-331	7	-403	-331	2572	27½
E-4	27	-63	-350	34	-55	-351	-1978	14¾
E-5	40	-16	-214	45	-13	-215	1338	14¾
E-6	41	-3	-179	45	0	-180	1196	15¾
E-7	20	0	-144	23	3	-144	956	18¾
F-1	-19	-252	-36	-18	-251	-36	2040	43¾
F-2	-269	0	-26	-268	6	-20	1788	25¾
F-3	-253	-147	-29	-252	-145	-26	1000	1½
F-4	0	38	-60	-1	40	-60	864	-33
F-5	-55	40	-52	-54	42	-51	826	44½
F-6	-6	12	0	-6	12	0	1156	38
G-1	-44	-277	9	-44	-276	10	2338	42
G-2	-27	-110	124	-29	-112	125	1630	32¾
G-3	-95	-218	119	-97	-216	121	2270	32¾
G-4	-150	89	181	-154	88	184	1650	11¾
G-5	-58	82	129	-61	80	130	958	12½
G-6	162		-55	163		-58		
G-7	-37	98	131	-40	96	132	896	15¼

TABLE XII.

CALCULATED STRAIN GAGE DATA

Run Number: 4 — 23 August 1946

Beam Span 7 feet — Load Position 1½ feet from near support

	Load (pounds)		
	2500	3500	4500
A-1	-123	-171	-229
A-2	-178	-257	-338
A-3	-184	-265	-347
B-1	-25	-37	-49
B-2	-29	-43	-56
B-3	21	29	38
B-4	-124	-179	-234
B-5	38	55	70
B-6	-158	-228	-301
B-7	120	187	247
B-8	-188	-273	-357
B-9	38	59	80
B-10	-181	-262	-345
B-11	47	65	86
B-12	-173	-249	-329
B-13	-162	-233	-304
C-1	-40	-58	-75
C-2	-151	-219	-286
C-3	-188	-273	-355
C-4	-160	-231	-302
D-1	-36	-53	-70
D-2	-165	-239	-314
H-1	49	72	94
H-2	100	145	190
H-3	186	269	352
H-4	208	300	393
H-5	189	274	358
H-6	155	226	298
H-7	146	212	277

TABLE XIII.
CALCULATED STRAIN GAGE DATA

Run Number: 6. 26 August 1946

Beam Span 4 feet Load Position 1½ feet from near support

Load 2500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3	γ_m	ϕ
E-1	-18	-97	-11	-18	-98	-11	-750	45 3/4
E-2	13	-113	-51	14	-114	-51	900	55 1/4
E-3	7	-135	-100	9	-136	-100	1200	52 7/8
E-4	0	23	-102	2	25	-102	-824	27 1/2
E-5	18	25	-68	19	27	-68	-592	24 1/4
E-6	20	39	-54	21	41	-54	-614	28
E-7	8	44	-27	9	45	-27	-512	35 3/8
F-1	-4	-113	-17	-4	-115	-17	944	42 1/2
F-2	-117	1	-18	-117	4	-16	800	61 1/2
F-3	-108	-60	39	-109	-60	41	-690	-8 3/4
F-4	0	49	-14	0	50	-14	-574	40 3/4
F-5	0	57	-4	0	58	-4	-540	43 1/2
F-6	0	54	-1	0	55	-1	-498	44 1/2
G-1	-23	-125	0	-23	-128	0	-1078	47 1/2
G-2	-11	-83	30	-12	-87	30	-902	50 1/2
G-3	-42	-70	67	-43	-72	68	-920	61 1/4
G-4	-55	67	74	-57	68	75	780	69 1/2
G-5	-16	45	33	-17	46	33	599	62 1/2
G-6	-12		42	-13		42		
G-7	-16	56	19	-16	57	19	824	53 1/4

TABLE XIV.

CALCULATED STRAIN GAGE DATA

Run Number: 6 — 26 August 1948

Beam Span 4 feet — Load Position 1½ feet from near support

Load 3500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3
E-1	-25	135	-17	-25	139	-17
E-2	18	-158	-71	19	-160	-71
E-3	11	-226	-141	14	-228	-141
E-4	0	41	-140	-3	45	-140
E-5	26	35	-93	28	37	-94
E-6	28	55	-75	30	58	-76
E-7	12	61	-38	13	63	-38
F-1	-6	-158	-23	-6	-161	-23
F-2	-151	2	-26	-150	3	-25
F-3	-152	-85	55	-153	-89	54
F-4	0	69	-21	0	70	-21
F-5	0	79	-6	0	81	-6
F-6	0	77	-2	0	79	-2
G-1	-31	-174	0	-31	-177	1
G-2	-15	-118	+42	-16	-121	42
G-3	-57	-97	94	-59	-101	95
G-4	-74	93	104	-76	93	102
G-5	-22	82	45	-23	82	44
G-6	-18		58	-19		57
G-7	-22	78	27	-23	80	27

TABLE XV.

CALCULATED STRAIN GAGE DATA

Run Number: 6 — 26 August 1946

Beam Span 4 feet — Load Position 1⅓ feet from near support

Load 4500 pounds

	ε_1'	ε_2'	ε_3'	ε_1	ε_2	ε_3	τ_m	ϕ
E-1	-27	-174	-24	27	-176	-23	-1358	45½
E-2	23	-203	-92	25	-206	-92	-1636	55¼
E-3	20	-290	-180	24	-293	-180	-2140	-31½
E-4	0	51	-182	4	56	-182	-1560	28½
E-5	35	45	-130	39	48	-131	-1076	23½
E-6	35	70	-97	37	72	-98	-1100	28¼
E-7	15	79	-50	16	82	-50	-902	55
F-1	-7	-198	-28	-6	-201	-31	1610	45½
F-2	-209	2	-33	-207	7	-29	1370	62¾
F-3	-193	-198	71	-197	-198	75	-1286	80½
F-4	0	89	-26	1	92	-26	-958	41
F-5	0	101	-9	0	105	-9	-976	52½
F-6	0	98	-2	0	100	-2	-980	44¼
G-1	-41	-224	1	-41	-227	2	-1890	47¾
G-2	-20	-152	55	-21	-154	55	-1584	51
G-3	-73	-125	122	-75	-129	123	-1648	61
G-4	-93	118	135	-96	119	137	1368	69¾
G-5	-29	81	+59	-28	85	60	728	61¼
G-6	-25		-75	-23		-74		
G-7	-30	101	55	-31	103	34	962	53¾

TABLE XVI.
CALCULATED STRAIN GAGE DATA

Run Number: 6 26 August 1946

Beam Span 4 feet Load Position 1½ feet from near support

	Load (pounds)		
	2500	3500	4500
A-1	-88	-123	-158
A-2	-43	-109	-255
A-3	-98	-138	-178
B-1	0	0	0
B-2	-21	-29	-37
B-3	26	34	43
B-4	-87	-123	-160
B-5	37	52	67
B-6	-118	-165	-213
B-7	107	150	193
B-8	-135	-189	-243
B-9	38	48	61
B-10	-135	-177	-228
B-11	28	37	48
B12	-91	-127	-166
B-13	-57	-79	-101
C-1	-16	-22	-28
C-2	-115	-159	-208
C-3	-150	-180	-231
C-4	-47	-66	-85
D-1	-24	-32	-44
D-2	-154	-216	-277
H-1	53	73	95
H-2	80	114	146
H-3	154	216	279
H-4	198	234	302
H-5	123	172	222
H-6	79	112	145
H-7	44	62	80

TABLE XVII.

STRAIN GAGE DATA

Run Number: 1 Load Position at Column 5

Vertical Reference Line Spacing = Inches Between Lines.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A						166	157	152	148½	145	146	136	136		
B															
C		10	8	5		150	150	146	146	137	137	136	133		
D															
E		16	18			157	140	141	138	135	137	133	129		
F															
G		35½	46½	70½	111	127	135	155	175	135½	170½	130	126		
H															
I		67½	75	83	136	123	127	131	132	128	124	122	124	120	
J															
K		77½	74½	85½	103½	113	119	119	122½	130	130	129	128	105	
L															
M	82	80½	81	88½	99	108	113	118	120	123	128	132	135	90	80

NOTE: Short End of beam is to right.

TABLE XVIII.

STEEL BOOM CRANE ANGLE DATA

Load Number: 3 Load Position at Mean R

Typical Reference Line Spacing: 1 Inch Between Lines.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A																
B																
C																
D																
E		36	37	40												
F																
G	41½	42½	44½	49	52											
H																
I	46	48	52½	58	66½	78	84½	100	112½	117	115					
J																
K	58	58	61	67	74	81½	85	93½	103	103½	103					
L																
M	61	62	67	71	75½	83½	89½	99	100	101	103	103	103	103½	103	

TABLE XIX.

STRESSCOAT CRACK ANGLE DATA

Run Number: 5 Load Position at Column 10

Vertical Reference Line Spacing 1 inch Between Lines.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A					15	13	11½	13					175	175			
B																	
C				16	16½	18	19	19					175	176	178		177½
D																	
E				24½	23½	22½	23½	26					172½	174	175½	172	170½
F																	
G				41	39	38	38½	44	51½	59		142½	146	142½	144	143	143
H																	
I			55	54½	54	58½	60½	65½	72½	75	88	95½	98	101	100	99½	99
J																	
K		59½	58½	62	66	72½	76	78½	80	82	91	96½	99	97½	97½	100	101½
L																	
M	66½	70	70	74	78½	80	80	80	81½	88	92	93	94	94	98	95½	95

TABLE XIX. (cont'd.)

STRESSCOAT CRACK ANGLE DATA

Run Number: 3 Load Position at Column 10

Vertical Reference Line Spacing 1 inch Between Lines.

	18	19	20	21	22	23	24
A							
B							
C	176	174	175				
D							
E	174	175	172				
F							
G	142	143	144				
H							
I	99	98	99½	100	101		
J							
K	98½	100	103	96½	100	101	
L							
M	94	95	98½	93½	94	98	98½

TABLE XX.

STRESSCOAT CRACK ANGLE DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A				12	8	6½	8½	10	10½	9	9½	10	10	9½	9	8½	8½
B			17½	11	8	9½	8½	9	8	8	11	10	10½	10	8½	8	8
C		17½	13	11	10	10½	9½	8½	9	11½	13	11½	10	9	8	9	10
D		18½	16	14½	14	12	11½	9½	11	9½	10	12	11	10½	11	10	12
E		30	25	23½	21	20	15½	13	14	14	15	15	16	14	14	13	11
F		37½	33	28	29	22	32	23	21½	17½	17½	16	16	14	15½	14	12
G	38	35½	43½	37	37½	39	38	44	35	33	32	30	31	32	28	26	24½
H	45	47	53	52	52	57	55½	60½	60½	62	65	65	66	63	71	69	67
I	54	60	60	61½	60	63	67	69	73	74	75½	78	79	79½	75	72	71½
J	61½	61	65	67	70	71	72	73	75	76	77	76½	75½	75½	75½	75	76
K	80	80	74	78	75	77½	77	79	76	80	77	78	79	78	77	77	76
L	78	77	77	77	79	73	80½	79	79½	78	78	78	73	79	78½	79	77
M	70	73	81	71	72	82	80	82	81	79	80	80	80	71	80	80	80

NOTE: Short end of beam is to the right.

TABLE XX. (cont'd.)

Run Number: 5 Load Position at Column 23

Vertical Reference Lines Spaced 1 Inch Between Lines.

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
A	8	6	5½	13½					170	169	168	165	162½	162	157	164	160½	158	
B	6	7	15	47		99	138	192	166	170	168	166	163	164	167	169	165	160	
C	9	8	9½	15	30½	100½	148½	180	167	164½	159	160	148	161	156½	150	172	167	
D	11	9½	10½	18	30½	117½	148½	166½	172	161	150½	157	153	157	153	154	152	150	157
E	10½	10	17½	18	31	128	147	155	157	158	155	156	150	170	156	157½	141	140	146
F	11	19½	21	28	31	161	141	142	141½	161	143	146½	140	144	141	146	142	147	147
G	21	21	28	35	48	128½	151	158½	130	141	144	140½	153	170	137	146½	134	132	130
H	67	67	68½	71	81½	96	138	170½	130	149	134	135	134	142	178	171	141	178	174½
I	74	75½	79½	80	87	94	131	112½	116	150	120	117	109½	178	134	146	150	147	150
J	74½	74½	75½	78	88	81½	103½	104	113	110	118	111	117	128	110	171	171½	177	172
K	76	77½	78	80	87	90	97	102½	105½	108	107	113	131	170½	108	137	151	149½	
L	77	78	80	83	84	90	97	98	103	102	108	146½	108	138	134	110	110	111	112
M	79	78	79½	81	82	90	98½	100½	106	131	136½	111	203½	136	111	117½	114	110½	

TABLE XXI.

[illegible]

Load Position at Column 10

Vertical Deflection Lbs. Cyl. 1 Inch Diameter.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	98	99½	99½	100	97½	97	101	111	144	17	45	[illegible]	71	76	75	70	66	71
B	97½	105	104	105	100	99	108	110	141	13	42½	[illegible]	67	82	[illegible]	67	72	74
C	101	106½	102½	110	106	104	110	114	148	12½	36	54	57½	69	61½	61½	68	74
D		107	108	104½	107	107	114	117		13	37	55	58	86	61	58	59	71½
E		111	105	107½	106	106½	104	130		12	33	48	57	51½	57	54	50½	65
F		113	114	116½	122	125½	127	135	0	9	31	45	48½	45½	47	51	53½	54
G		117	110½	115½	125½	130½	116	143	0	13	30	50	47	42½	41	44	50	50
H			125	131½	120	113	129½	163½	0	11	13	30	39	36	40½	40	40	
I			128	136½	140½	131½	160½	160	0	11	16	32	26	36	31	43½	41	
J			137	143	143½	157	162	164½	0	5	14	19½	21	27½	33	35	31½	
K			135½	155½	130½	130	165½	169	0	3	14	13½	21½	27	33	35	32	
L				158	154	150	170	173	0	4	9	16	16½	30½	33½	33½		
M					162	166½	171	172	0	4	12	16	15	16	16			

NOTE: Short end of beam is to right.

TABLE XXII.

STRESSCOAT CRACK ANGLE DATA

Run Number: 9 Load Position at Column Ln.2

Vertical Reference Line Spacing 1 inch Between Lines.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A							1	13					163½	164	162	153	
B						0½	0	13	48½				160½	162	158½	158½	
C				10½	5	3	2	14	50	98			151½	158	161	158	154
D			17	13	7	6	6	14	54	107	122	143	154	155	149½		
E			21	19	10	9	10	16½	56	116	138	142	148	148	148		
F		32	27½	27	23	21½	22½	28	75	117½	136	134½	145	141½			
G		41	41½	38½	34	36	32½	53½	90	117	133½	133	138	141½			
H		53½	50½	50½	47½	42½	58	76	90	108	117	127	153	134½			
I		66½	66	58	63	65	70½	79	90	101	113	124	134	132½			
J		68	66½	66	69½	74	77	31	96	101	109	116	129½	123			
K	78	76½	72½	74	74	82	83	86½	88	98½	108	119½	116	115			
L	74½	77	77½	77	80	84	85½	83½	84	98½	106	109	113	115			
M	80	80	78	77½	82½	85½	86½	85	86	90½	106½	109½	109½	113	112		

APPENDIX C.

SAMPLE CALCULATION

Part I. Computation of Shear Stress from Strain Gage Readings.

Calculation for Run No.3, 19 August 1946, Gage F-5

Load = 2500 pounds.

From [illegible] readings:

$\varepsilon_1' =$ [illegible]

$\varepsilon_2' =$ [illegible]

$\varepsilon_3' = -57$

Then: $\varepsilon_1 = \varepsilon_1' - \mu\varepsilon_3'$

$\varepsilon_2 = [illegible] - \mu(\varepsilon_1' + \varepsilon_3')$

$\varepsilon_3 = \varepsilon_3' - \mu\varepsilon_1'$

For this gage, $\mu = .0213$

Therefore,

$\varepsilon_1 = [illegible] - (.0213)(-57)$

$\varepsilon_1 = -10 + 0.71$

$\varepsilon_1 = -19$

$\varepsilon_2 = (1.02)(26) - (.0213)(-57)$

$\varepsilon_2 = 26.5 + 1.21$

$\varepsilon_2 = [illegible]$

$\varepsilon_3 = [illegible] - (.0213)(-20)$

$\varepsilon_3 = -57 + .43$

$\varepsilon_3 = -57$

From Nomograph Solution for Shear Stress

$\tau_m = -500$ lbs/sq.in

$\phi = -40°$

Part II. Computation of Shear Stress from Simple Beam Formulas:

For Run No. 3, 19 August 1940, Position F-5

W = 2500 lbs.

A = 2 ft.

B = 3 ft.

L = 5 ft

$$V = -\frac{WA}{L}$$

V = - 1000 lbs.

Q = 8.04 in.^{3} (obtained by integrating tracing of beam cross-section)

I = 78.6 in.4 (obtained as above)

b = .28 in. (from direct meas.)

$$\tau_{31} = \frac{VQ}{Ib}$$

$$= \frac{(-1000)(8.04)}{(78.6)(.28)}$$

τ_{31} = -516 lbs/sq.in

$$M_x = \frac{WA}{L}(L-X)$$

$$= \frac{(2500)(2)}{5}(5-2.25)$$

$$= (2500)(2)(2.75)$$

M = 2750 ft. lbs.

C = 0

σ_3 = 0

σ_1 = 0 (assumed)

$$\tau_m = \pm \sqrt{\left(\frac{\sigma_3 - \sigma_1}{2}\right)^2 + \tau_{31}^2}$$

$$= \pm \sqrt{0 + (516)^2}$$

τ_m = ± 516 lbs/sq.in

b. For Run No. 1, 17 August 1946, Gage Position E-2

W = 4500 lbs.

A = 2 ft

B = 5 ft

L = 7 ft

C = 2 in.

b = .28 in.

By integration of section

$Q = 7.54 \text{ in.}^3$

$V = \frac{WB}{L}$

$= \frac{(4500)(5)}{7}$

V = [illegible] lbs/ft.in

$\tau_{31} = \frac{VQ}{Ib}$

$= \frac{([illegible])(7.54)}{([illegible])(.28)}$

= [illegible] lbs/sq.in

$M = \frac{WBX}{L}$

$= \frac{([illegible])([illegible])(.75)}{7}$

M = 2410 ft. lbs.

$\sigma_3 = \frac{Mc}{I}$

$= \frac{(2410)(2)(12)}{55.8}$

$\sigma_3 = 1040$ lbs/sq.in

$\sigma_1 = 0$ (assumed)

$\tau_m = \pm \sqrt{\frac{(1040)^2}{2} + (1557)^2}$

$\tau_m = \pm$ 1843 lbs/sq.in.

APPENDIX D

OBSERVED DATA

DESCRIPTION OF DATA:

STRESSCOAT DATA

This data is presented as loading data and crack angle data. The loading data provides information on type of load, position of load, etc., for each test run. The crack angle data summarizes the angles of the individual Stresscoat cracks. These angles were measured from the horizontal in a counter clockwise direction from the right. These data provide information which would enable any person to reconstruct the tensile strain pattern for each load listed. The method of obtaining this crack angle data was as follows:

1. After completion of the test run and application of CO_2, the beam was removed from the testing machine and a rectangular reference grid system marked off covering the area of the crack pattern. The reference lines were run parallel to the assumed neutral axis and at right angles to the assumed neutral axis. The columns (numbered 1, 2, 3, etc.) represent lines drawn perpendicular to the neutral axis, and lines (lettered A, B, C, etc.) represent lines parallel to the neutral axis.

2. The angle of cracking was then measured at each intersection of the grid reference lines.

3. Explanation of labelling of reference lines.

a. Low numbers are to the left, looking towards the beam, in all cases.

b. Unless otherwise stated, the short span is to the left.

c. Longitudinal reference lines are spaced ½ inch between lines; vertical reference lines are spaced as noted on each data sheet.

4. The position of the beam neutral axis is on reference line G.

STRAIN GAGE DATA

Data is presented for each test load of each run made, in the sequence of loading. From this observed data the observed values were faired, and the faired data used to obtain values of strain for calculation of results. The strain indicator reference position value was omitted from these tables of observed data, since all data under each reading are based on the same reference position. The values given in the columns under each load are expressed in micro-inches per inch.

Run Number 1

Date: 10 July 1946

Beam Span 7 feet

Instrument Data:
[illegible]
Sensitivity .[illegible] in/in

Load Data:
(Compression (or Tension))
Load Position 1½ feet from near support

Loading time (sec.)	Total Load (Lb.)	Effective Load (Lb.)	Time Required (Sec.)	Cycle Time (Sec.)	Remarks (Cracks and Others)
45	5440	[illegible]	275	345	None
70	5000	[illegible]	220	370	None
175	4550	4550	140	320	None
170	5820	5820	290	490	Top of Bottom Flange and [illegible] of Web Beneath Load
207	6910	6910	378	590	Increased "Crack" Area

TABLE XXIV

[illegible]

Run Number 2

Date: 12 July 1946

Beam Span 7 feet

Strescoat Data:
Number 1200
Sensitivity:

Load Data:
(Compression (or Tension)
Load Position 1/3 feet from near support

Loading Time (sec.)	Scale Load (lbs.)	Effective Load (lbs.)	Time Unloaded (sec.)	Cycle Time (sec.)	Remarks (Crack Locations)
42	3000	3000	81	173	None
10	4060	4060	58	75	Top of Bottom Flange Above near Support
61	5000	5000	65	132	No Increases
152	6010	6010	101	256	Bottom of Bottom Flange Beneath Load
195	6970	6970	115	320	Increased Crack Areas

Beam Number 3

Beam Span 7 feet

Date: [illegible]

Load Data:
[illegible] (or Tension)
Load Position 2 feet from near support

Instrumental Data:
[illegible]
Sensitivity .0074 in/in

Loading Time (Sec.)	Dead Load (Lbs.)	Effective Load (Lbs.)	Time Underload (Sec.)	Cycle Time (Sec.)	Remarks (Crack Locations)
100	[illegible]	2980	128	230	Top of top flange and bottom of bottom flange when load was released, Rowing load off center
132	3950	7930	180	522	Increased area on top of top flange New crack area on top of bottom flange
180	4040	4040	147	295	New area at bottom of web beneath load
210	5870	[illegible]	310	[illegible]	Increased crack area

TABLE XXVI

STRESSCOAT LOADING DATA

Run Number 4

Date: 10 July 1946

Beam Span 7 feet

Stresscoat Data:
Number 1[illegible]

Load Case:
Compression (or Tension)
Load Position 1 Feet from [illegible] support

Loading Time (Sec.)	Scale Load (Lbs.)	Effective Load (Lbs.)	Time Unloaded (Sec.)	Cycle Time (Sec.)	Cracks (Direct Location)
		(Initial Load 5520 pounds)			
35	1040	4480	30	130	None
48	2080	3440	122	147	None
71	1620	3710	140	220	None
95	[illegible]	4680	180	196	None
70	80	5440	75	145	None

TABLE XXVII

SCHEDULE OF FLOAT LOADING DATA

Run Number 5

Date: 22 July 1946

Beam Span 7 feet

Strain Gage Data:

Load Data:

Number 1203

Tension Load

Sensitivity .00083 in/in

Load Position 2½ feet from near support

Loading Time (Sec.)	Scale Load (lbs.)	Effective Load (lbs.)	Time Underload (Sec.)	Cycle Time (Sec.)	Remarks (Crack Locations)
77	2970	2970	91	187	None
66	3980	3980	98	171	Top of bottom flange beneath load. Bottom of bottom flange beneath load.
60	4450	4450	150	217	Increased areas as above
108	5030	5030	214	329	Increased areas as above. Bottom of web beneath load.
107	5440	5440	113	230	Increased areas as above
168	5920	5920	314	468	Increased areas as above

TABLE XXVIII

STRESSCOAT LOADING DATA

Run Number 6

Date: 13 July 1946

Beam Span 7 feet

Stresscoat No. Lb:
Sensitivity .00[illegible] lb/in

Load Data:
Compression (or Tension)
Load Position 2 feet from near support

Loading Time (Sec.)	Scale Load (lbs.)	Effective Load (lbs.)	Time Underload (Sec.)	Cycle Time (Sec.)	Remarks Crack Location
75	2960	2960	81	164	None
76	3470	3470	38	131	None
68	3970	3970	155	228	Top and bottom of bottom flange beneath load
90	4448	4448	170	270	Increased [illegible] as above. Also bottom of web beneath load.
115	[illegible]	[illegible]	175	[illegible]	Increased [illegible] as above
180	5410	5410	248	438	Increased areas as above

TABLE XXIX

[illegible]

Run Number 7

Date: 26 July 1946

Beam Span 7 feet

Strain Gage Data:
[illegible]

Load Data:
[illegible] (or Type of)
Load Position 2 feet from near support

Loading Time (Sec.)	Scale Load (lbs.)	Effective Load (lbs.)	Time Undertone (Sec.)	Cycle Time (Sec.)	Remarks (Crack Locations)
	810	810		270	None
	660	660		480	Top and bottom of bottom flange beneath load
	810	810		710	Increased areas as above. Bottom of web beneath load
	[illegible]	[illegible]		600	[illegible]

Note: This beam was 5" x 2 3/8" I section.

TABLE XXX

[illegible]

Run Number 8

Date: 27 July 1940

Beam span 7 feet

Strain Gage Data:
[illegible]
Sensitivity .00071 in/in.

Load Data:
No Correction (or Tension)
Load Position 2 feet from each support

Bearing Time (Sec.)	Gage Load (Lbs.)	Effective Load (Lbs.)	Time Deflection (Sec.)	Gage Time (Sec.)	Remarks (Note Location)
	4700	0			
60	[illegible]	[illegible]	78	170	[illegible]
	4710	0			
85	2590	2280	108	245	None
	4770	0			
65	2000	2770	82	207	None
	4770	0			
68	1180	3510	148	368	None
	4760	0			
48	1130	3650	291	417	Upper web filler under load. Top of top flange
	4740	0			
172	570	4140	93	406	Increased areas as above

TABLE XXXI

STRESSCOAT LOADING DATA

Run Number 9

Date: 29 July 1946

Bead Span 6 feet

Stresscoat Data:

Load Data:

Number

Tension Load

Sensitivity in/in

Load Position 2 feet from near support

Loading Time (Sec.)	Scale Load (Lbs.)	Effective Load (Lbs.)	Time Underload (Sec.)	Cycle Time (Sec.)	Remarks (Crack Locations)
32	3270	3270	105	202	None
35	3870	3870	129	168	None
15	4560	4560	55	75	Top of bottom flange at near support
100	5260	5260	45	155	Increased areas as above
65	5950	5950	55	125	Increased areas as above
90	6410	6410	150	240	Increased areas as above. Bottom of web beneath load.

TABLE XXXII

STRAIN GAGE READING NUMBERS vs. STRAIN GAGE NUMBERS

Reading Number	Gage Number	Reading Number	Gage Number	Reading Number	Gage Number
1	B-5	31	E-6-3	66	G-5-3
2	B-6	32	E-6-2	67	G-5-2
3	C-2	33	E-6-1	68	G-5-1
4	B-7	34	E-5-3	69	H-5
5	A-2	35	E-5-2	70	G-4-3
6	B-8	36	E-5-1	73	G-4-2
7	B-9	37	E-4-3	74	G-4-1
8	B-10	38	E-4-2	75	H-4
9	C-3	39	E-4-1	76	G-3-3
10	B-11	40	E-3-3	77	G-3-2
11	A-3	41	E-3-2	78	G-3-1
12	B-12	42	E-3-1	79	H-3
13	B-13	43	F-5-1	80	G-2-3
14	C-4	44	F-5-3	81	G-2-2
15	E-2-3	45	F-4-3	82	G-2-1
16	E-2-2	46	F-4-2	83	H-2
17	E-2-1	47	F-4-1	84	G-1-3
18	E-1-3	48	F-3-3	87	G-1-1
19	E-1-2	49	F-3-2	88	G-1-2
20	E-1-1	50	F-3-1	89	H-1
21	D-1	51	F-2-3	90	F-6-1
22	D-2	52	F-2-2	91	F-6-2
23	B-1	53	F-2-1	92	F-6-3
24	B-2	54	F-1-1	93	G-7-1
25	C-1	55	F-5-2	94	G-7-2
26	B-5	61	H-7	95	G-7-3
27	A-1	63	G-6-3	96	E-7-1
28	B-4	64	G-6-1	97	E-7-2
29	F-1-3	65	H-6	98	E-7-3
30	F-1-2				

TABLE XXXIII

STRAIN GAGE CONSTANTS

Gage Number	Gage Factor	Auxiliary Factor	Calibrated Res.(ohms)
A-1	2.04		119.6
A-2	2.09		120.0
A-3	2.09		120.0
B-1	2.04		119.6
B-2	2.04		119.6
B-3	2.04		119.6
B-4	2.04		119.6
B-5	2.04		119.6
B-6	2.04		119.6
B-7	2.04		119.6
B-8	2.09		120.0
B-9	2.09		120.0
B-10	2.09		120.0
B-11	2.09		120.0
B-12	2.09		120.0
B-13	2.09		120.0
C-1	2.04		119.6
C-2	2.04		119.6
C-3	2.09		120.0
D-1	2.09		120.0
D-2	2.09		120.0
E-1	2.07	.0200	120.1
E-2	2.07	.0200	120.1
E-3	2.07	.0200	119.9
E-4	2.07	.0200	119.9
E-5	2.07	.0213	120.3
E-6	2.07	.0213	120.1
E-7	2.07	.0213	120.1
F-1	2.07	.0200	120.1
F-2	2.07	.0200	119.9
F-3	2.07	.0200	119.9
F-4	2.07	.0213	120.3
F-5	2.07	.0213	120.3
F-6	2.07	.0213	120.1
G-1	2.07	.0200	120.1
G-2	2.07	.0200	120.1
G-3	2.07	.0200	119.9
G-4	2.07	.0213	120.3
G-5	2.07	.0213	120.3
G-6	2.07	.0213	;20.1
G-7	2.07	.0213	120.1
H-1	2.09		120.0
H-2	2.09		120.0
H-3	2.09		120.0
H-4	2.09		120.0
H-5	2.09		120.0
H-6	2.09		120.0
H-7	2.09		120.0

TABLE XXXIV

OBSERVED STRAIN GAGE DATA

Run Number: 1 Date: 17 August 1946

Beam Span 7 feet Load Position 2 feet from near support

Reading Number	Load (pounds) 500	2530	3520	4460
1	1006	1050	1060	1025
2	1217	1081	1009	922
3	699	771	682	596
4	1133	1185	1202	1263
5	842	680	545	418
6	1154	972	881	678
7	1172	1366	1420	1552
8	1291	1100	983	679
9	258	115	042	622
10	390	449	480	553
11	529	337	221	018
12	1104	902	730	600
13	1259	1088	969	853
14	890	730	680	530
15	1007	1011	908	900
16	440	330	271	225
17	102	110	110	118
18	822	909	890	788
19	629	538	488	440
20	450	430	420	418
21	286	260	250	231
22	735	629	570	517
23	150	158	158	163
24	516	482	485	481
25	1032	1009	990	980
26	559	559	563	578
27	285	188	141	097
28	1012	921	878	840
29	909	909	900	898
30	594	389	240	193
31	570	459	382	292
32	890	890	890	880
33	290	315	340	379
34	1040	800	778	530
35	599	482	479	423
36	600	651	697	760
37	529	381	302	136
38	720	547	473	340
39	585	582	616	670
40	169	109	068	082
41	948	851	773	720
42	600	621	627	652
43	532	521	532	542
44	677	647	651	630
45	402	422	432	471

TABLE XXXIV (CONT.)

OBSERVED STRAIN GAGE DATA

Run Number: 1

Date: 17 August 1948

Beam Span: 7 feet

Load Position: 2 feet from near support

Reading Number	Load (pounds) 300	3360	3840	4400
46	888	815	771	712
47	818	300	751	689
48	399	380	382	395
49	590	479	427	373
50	720	702	707	711
51	800	790	790	798
52	470	450	470	460
53	828	716	670	620
54	139	121	120	120
55	668	693	722	760
61	605	779	873	1020
63	295	244	228	220
64	032	112	173	311
65	894	1088	1230	1490
66	535	613	809	873
67	708	753	792	900
68	1140	1086	1040	971
69	619	867	1102	1703
70	710	796	888	1062
73	269	200	171	170
74	979	911	900	842
75	884	1104	1275	1708
76	1387	1452	1462	1510
77	684	610	570	547
78	1075	1038	1030	1033
79	371	490	580	678
80	626	643	667	697
81	291	209	186	150
82	700	671	662	673
83	382	456	491	540
84	274	297	276	293
87	745	701	698	710
88	1459	1540	1274	1205
89	1450	1491	1533	1545
90	810	797	799	783
91	792	821	834	850
92	761	765	760	753
93	920	883	865	860
94	512	362	387	430
95	253	323	367	445
96	922	939	950	990
97	271	266	272	290
98	585	455	406	380

TABLE XXXV

OBSERVED STRAIN GAGE DATA

Run Number: 2 Date: 19 August 1946

Beam Span 6 feet Load Position 2 feet from near support

Reading Number	Load (pounds) 500	2515	3435	4480	510
1	1230	1219	1260	1290	1190
2	1391	1251	1195	1139	1375
3	1010	853	800	740	1000
4	1353	1372	1471	1428	1333
5	951	743	730	585	920
6	1380	1170	1115	1010	1340
7	582	669	740	772	570
8	1269	1072	1009	902	1240
9	392	199	149	012	350
10	629	659	708	720	618
11	710	520	445	358	705
12	500	300	249	149	480
13	1390	1221	1170	1088	1372
14	881	710	670	580	878
15	1265	1189	1189	1158	1237
16	620	499	464	411	611
17	1230	1219	1242	1323	1222
18	1015	987	989	969	991
19	732	698	670	628	729
20	610	589	600	581	605
21	479	422	430	410	451
22	1148	1003	955	901	1133
23	1370	1328	1359	1340	1340
24	712	668	695	660	699
25	1181	1129	1139	1110	1151
26	714	719	748	740	698
27	1380	1288	1275	1219	1372
28	1180	1068	1042	1003	1161
29	1152	1124	1140	1122	1139
30	619	480	498	398	598
31	680	542	521	457	642
32	975	960	980	963	961
33	1310	1348	1340	1340	1310
34	969	852	790	700	940
35	520	520	525	501	518
36	842	781	813	815	825
37	1550	1402	1353	1273	1449
38	810	610	547	468	792
39	798	730	739	740	768
40	697	615	589	540	677
41	1180	1002	965	910	1125
42	837	812	880	833	812
43	698	650	654	662	688
44	880	868	821	810	829
45	608	629	641	623	579

TABLE XXXV (CONT.)

OBSERVED STRAIN GAGE DATA

Run Number: 2 Date: 13 August 1946

Beam Span 6 feet Load Position 2 feet from near support

Reading Number	Load (pounds) 500	2515	5495	4480	510
46	965	890	872	851	951
47	991	859	820	770	978
48	726	700	690	660	680
49	820	730	659	596	798
50	927	882	886	879	909
51	1080	1082	1057	1030	1045
52	706	707	690	669	670
53	967	928	852	802	980
54	1278	1230	1305	1289	1288
55	819	855	870	880	829
61	960	1140	1195	1243	962
63	1335	1229	1276	1251	1300
64	1247	1325	1359	1371	1204
65	1477	1640	1732	1803	1452
66	1550	1642	1655	1678	1539
67	785	819	823	842	772
68	1200	1172	1120	1097	1180
69	705	930	1040	1144	715
70	1017	1168	1177	1216	1024
73	1338	1387	1317	1301	1372
74	1066	1073	1031	1000	1080
75	576	783	852	950	550
76	693	763	797	770	656
77	885	846	773	743	858
78	1275	1270	1221	1212	1256
79	1704	1852	1902	1970	1692
80	1718	1768	1779	1797	1711
81	1443	1406	1385	1506	1424
82	872	889	900	840	844
83	1563	1626	1652	1678	1587
84	1410	1421	1410	1401	1404
87	943	939	936	900	932
88	780	827	832	570	730
89	780	879	842	862	780
90	898	918	903	910	900
91	930	988	965	990	899
92	830	820	795	800	798
93	1030	1000	983	970	1010
94	1383	1395	1410	1442	1317
95	1370	1460	1480	1513	1382
96	1060	1103	1100	1115	1062
97	458	442	435	441	402
98	700	665	583	553	690

TABLE XXXVI

OBSERVED STRAIN GAGE DATA

Run Number: 3 Date: 19 August 1946

Beam Span 5 feet Load Position 2 feet from near support

Reading Number	Load (pounds) 490	2480	3510	4535	515
1	1155	1150	1159	1152	1168
2	1349	1200	1129	1060	1266
3	1010	845	749	661	885
4	374	354	360	362	253
5	878	691	623	539	737
6	1349	1151	1055	973	1240
7	528	612	649	676	456
8	1228	1043	939	841	1125
9	1526	1132	1066	970	1227
10	572	582	585	590	490
11	660	486	378	280	568
12	488	296	212	118	380
13	1366	1206	1131	1052	1252
14	896	739	680	613	812
15	1221	1138	1098	1064	1119
16	583	461	396	332	498
17	1212	1160	1150	1141	1108
18	871	910	890	870	868
19	788	649	596	540	672
20	588	518	501	480	482
21	1380	1298	1279	1238	1264
22	1130	988	901	836	1033
23	1338	1262	1249	1239	1210
24	1664	1597	1592	1552	1548
25	1132	1066	1040	1009	1020
26	698	649	641	630	579
27	405	270	232	180	295
28	1119	1008	965	909	1026
29	1149	1053	1044	1012	1029
30	1509	1377	1331	1261	1429
31	612	501	440	389	529
32	972	920	922	912	861
33	1333	1280	1298	1291	1231
34	905	766	700	630	811
35	1471	1409	1408	1401	1361
36	870	789	787	785	759
37	566	394	335	260	440
38	778	591	509	427	689
39	778	730	712	698	699
40	650	549	525	480	572
41	1145	980	910	860	103
42	836	779	770	772	730
43	682	631	613	619	599
44	839	752	740	723	720
45	580	539	552	559	472

TABLE XXXVI (cont)

OBSERVED STRAIN GAGE DATA

Run Number: 3 Date: 15 August 1946

Beam Span 5 feet Load position 2 feet from near support

Reading Number	Load (pounds) 490	2480	3510	4535	515
46	930	847	811	775	851
47	1002	830	775	720	892
48	650	602	591	580	668
49	796	639	583	532	680
50	810	830	820	802	792
51	1038	983	955	936	922
52	680	605	592	580	569
53	981	831	770	705	862
54	1255	1191	1151	1180	1160
59	830	801	819	820	708
61	822	990	1030	1060	840
63	330	300	270	232	252
64	1212	1205	1222	1246	1200
65	1435	1510	1570	1628	1323
66	642	655	685	712	580
67	810	800	812	836	751
68	1182	1081	1042	1015	1080
69	707	824	912	995	890
70	1018	1030	1058	1082	900
73	1340	1256	1220	1180	1242
74	1072	962	930	892	960
75	532	640	720	792	415
76	648	630	642	648	533
77	836	720	680	632	738
78	1240	1154	1132	1110	1198
79	720	816	812	853	617
80	772	746	738	730	660
81	1400	1290	1234	1194	1292
82	1763	1722	1704	1700	1682
83	1471	1518	1528	1547	1404
84	1336	1326	1304	1295	1270
87	890	800	794	790	770
88	736	574	517	472	620
89	737	749	745	746	660
90	903	853	835	826	810
91	870	892	900	910	802
92	767	757	740	732	728
93	1000	934	900	884	902
94	1318	1330	1338	1363	1333
95	392	410	417	427	322
96	1020	1017	1000	1000	965
97	357	367	357	360	297
98	650	580	520	480	560

TABLE XXXVII

OBSERVED STRAIN GAGE DATA

Date: 25 August 1946

Run Number: 4

Beam Span 7 feet Load Position 1½ feet from near support

Reading Number	Load (pounds) 500	2530	3495	4520	525
1	473	409	420	500	438
2	651	528	440	402	154
3	1237	1116	1033	998	1210
4	681	845	902	956	740
5	1205	1057	987	922	1220
6	732	578	498	450	755
7	706	809	828	841	755
8	541	357	280	200	505
9	780	605	538	456	745
10	846	883	882	897	821
11	941	732	718	641	954
12	960	822	729	661	935
13	1013	1468	1354	1328	1009
14	832	685	636	561	810
15	1128	1515	1370	1340	1440
16	882	744	690	627	860
17	548	528	536	530	522
18	1231	1198	1185	1165	1210
19	1047	951	878	829	1027
20	908	880	861	852	885
21	1634	1612	1560	1540	1600
22	1508	1322	1190	1156	1371
23	1582	1525	1521	1545	1551
24	951	890	880	870	921
25	1308	1310	1295	1295	1345
26	990	975	971	998	952
27	681	535	457	400	600
28	1341	1241	1190	1147	1326
29	1419	1405	1357	1340	1382
30	874	738	669	610	829
31	892	780	740	698	854
32	1229	1192	1177	1168	1190
33	630	610	611	630	585
34	1161	1058	1010	970	1142
35	760	745	734	734	747
36	1198	1180	1179	1197	1149
37	819	673	580	482	681
38	1147	1111	1079	1085	1085
39	1178	1141	1135	1203	1200
40	1101	966	885	815	990
41	1445	1248	1146	1078	1390
42	1219	1158	1165	1199	1212
43	1040	1001	986	999	1021
44	1081	1082	1042	1061	1072
45	830	796	785	765	800

TABLE XXXVII (CON'T)

OBSERVED STRAIN GAGE DATA

Run Number: 4 Date: 23 August 1948

Beam Span 7 feet Load Position 1½ feet from near support

Reading Number	Load (pounds) 500	2530	3415	4520	525
46	1281	1270	1269	1280	1245
47	1298	1281	1280	1291	1299
48	1028	1015	1022	1015	992
49	1110	1045	980	919	1048
50	1245	1105	1045	989	1102
51	1349	1280	1279	1274	1296
52	1048	995	993	999	1019
53	1250	1098	1040	978	1210
54	1593	1530	1546	1541	1557
55	1129	1113	1119	1130	1085
61	1296	1363	1418	1494	1250
63	637	563	551	541	589
64	543	551	593	634	500
65	907	990	1073	1140	877
66	820	842	873	900	799
67	1078	1060	1090	1106	1036
68	1430	1384	1387	1373	1420
69	1200	1348	1440	1523	1218
70	1233	1309	1362	1403	1240
73	1617	1653	1683	1714	1632
74	1378	1373	1280	1240	1328
75	805	1010	1133	1235	878
76	937	948	1000	1044	910
77	1142	1030	1000	950	1089
78	588	515	518	510	573
79	1087	1207	1307	1458	1120
80	1033	1013	1043	1071	992
81	1685	1565	1540	1514	1662
82	1130	1072	1087	1080	1102
83	1769	1820	1884	1925	1752
84	1657	1597	1617	1622	1617
87	1253	1182	1193	1183	1223
88	1104	949	905	840	1072
89	1075	1097	1133	1170	1078
90	1180	1153	1148	1138	1146
91	1182	1180	1195	1192	1155
92	123	87	80	83	83
93	1247	1187	1190	1180	1211
94	585	614	663	660	568
95	680	709	739	768	652
96	1380	1340	1356	1373	1352
97	615	643	653	662	652
98	980	892	820	732	915

TABLE XXXVIII

OBSERVED STRAIN GAGE DATA

Run Number: 5 Date: 26 August 1946

Beam Span 5 feet Load Position 1½ feet from near support

Reading Number	Load (pounds)				
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	381	479	437	513	450
2	816	520	468	409	632
3	1178	783	788	652	875
4	714	1212	1255	1302	1120
5	1229	1109	1046	988	1232
6	778	672	610	542	795
7	731	736	815	833	759
8	1447	1380	1260	1202	1455
9	730	660	582	548	782
10	788	838	852	870	808
11	940	852	803	738	956
12	934	900	855	805	1010
13	632	570	531	490	650
14	963	902	860	851	[illegible]
15	1430	1398	1372	1350	1445
16	817	898	850	591	[illegible]
17	459	459	464	469	460
18	1185	1180	1172	1169	1193
19	989	907	865	815	992
20	840	855	852	848	872
21	640	639	628	609	659
22	1424	1047	975	868	1180
23	1580	1550	1553	1538	1538
24	905	905	892	881	920
25	1328	1335	1321	1293	1350
26	940	983	991	1002	961
27	575	489	448	420	573
28	1313	1243	1200	1161	1323
29	1384	1417	1397	1392	1412
30	816	706	655	605	802
31	841	810	778	750	861
32	1133	1170	1163	1172	1148
33	488	525	530	541	520
34	1141	1112	1069	1038	1172
35	683	725	723	726	717
36	1105	1122	1132	1133	1110
37	1432	992	982	886	1072
38	1043	1017	1015	1017	1017
39	1110	1298	1288	1301	1311
40	1061	1260	1219	1168	1340
41	1563	1502	1320	1330	1544
42	1130	1109	1102	1120	1220
43	978	990	980	983	992
44	1041	1072	1071	1069	1075
45	774	807	799	7[illegible]	818

TABLE XXXVIII (CON'T)

Run Number: 5 Date: 28 August 1946

Beam Span 5 feet Load Position 1½ feet from near support

Reading Number	Load (pounds)				
	800	[illegible]	1500	1400	1200
46	1210	1472	1388	1300	1242
47	1230	1268	1282	1261	1276
48	945	900	915	930	870
49	1027	640	613	578	698
50	1119	821	775	727	923
51	1303	1325	1318	1309	1358
52	978	1032	1030	1034	1047
53	1182	998	949	895	1100
54	573	629	631	642	640
55	1085	1115	1130	1148	1081
61	325	400	439	478	381
63	584	567	560	550	580
64	501	519	573	596	505
65	900	1004	1057	1107	910
66	550	591	593	643	590
67	850	880	887	926	870
68	1395	1379	1372	1382	1402
69	1291	1418	1483	1349	1301
70	1230	1718	1758	1800	1652
73	873	1000	1024	1043	903
74	1317	1163	1168	1149	1284
75	872	1109	1250	1337	1020
76	914	1327	1360	1384	1270
77	1083	960	935	905	1030
78	577	576	582	552	614
79	1140	1198	1272	1350	1064
80	1000	1047	1063	1080	1019
81	715	640	610	580	714
82	1085	1162	1143	1143	1153
83	805	890	930	966	820
84	680	705	707	708	708
87	1207	1206	1209	1237	1242
88	1090	873	830	795	987
89	1207	1210	1232	1262	1175
90	1117	1114	1117	1117	1120
91	1120	1152	1172	1188	1120
92	950	948	947	950	958
93	1184	1170	1167	1160	1180
94	1424	1462	1483	1520	1435
95	641	677	696	713	645
96	1323	1335	1343	1352	1330
97	645	662	673	682	645
98	924	886	887	843	928

TABLE XXXIX

OBSERVED STRAIN GAGE DATA

Run Number: 6 Date: 26 August 1940

Beam Span 4 feet Load Position 1½ feet from near support

Reading Number	Load (pounds)				
	500	2500	3000	4500	4000
1	1077	1440	[illegible]	[illegible]	[illegible]
2	623	[illegible]	[illegible]	[illegible]	841
3	690	[illegible]	74[illegible]	[illegible]	[illegible]
4	1119	1209	1264	1501	1180
5	1242	1105	1062	1082	1247
6	800	692	640	530	805
7	759	785	7[illegible]	[illegible]	761
8	1486	1361	1325	[illegible]	1484
9	810	719	670	[illegible]	[illegible]
10	836	828	803	[illegible]	[illegible]
11	960	872	838	[illegible]	[illegible]
12	1025	948	912	876	1021
13	668	620	600	570	662
14	1017	978	958	929	1018
15	1450	1404	1387	1362	1448
16	800	719	673	633	816
17	463	478	492	490	478
18	1195	1182	1160	1172	1193
19	926	918	878	842	936
20	860	858	853	851	872
21	662	640	630	622	660
22	1220	1095	1028	989	1218
23	590	590	590	590	589
24	824	808	809	821	830
25	1355	1337	1317	1320	1352
26	961	979	988	996	959
27	1341	1462	1432	1392	1340
28	1260	1254	1221	1187	1327
29	1418	1416	1396	1381	1415
30	792	700	800	619	796
31	872	832	810	789	871
32	1151	1189	1161	1200	1151
33	1481	1502	1490	1506	1482
34	1180	1120	1095	1060	1179
35	720	742	751	761	721
36	1122	1142	1152	1169	[illegible]
37	1081	1000	960	913	1081
38	1027	1035	1065	1075	1036
39	1340	1355	1350	1358	1365
40	1252	1272	1253	1135	1252
41	618	491	430	372	681
42	1251	1260	1262	1269	1272
43	1005	1005	1005	1003	1010
44	1080	1079	1072	1068	1070
45	819	809	800	790	819

TABLE XXXIX (CON'T)

OBSERVED STRAIN GAGE DATA

Run Number: 6 Date: 28 August 1946

Beam Span 4 feet Load Position 1½ feet from near support

Reading number	500	2500	[illegible]	4000	[illegible]
46	1145	[illegible]	1312	1335	1252
47	1260	[illegible]	1286	1286	1291
48	879	[illegible]	929	942	881
49	704	658	681	612	711
50	941	833	812	770	965
51	1341	1327	1313	1319	1349
52	1049	1050	1052	1052	1061
53	1098	1003	981	919	1103
54	822	820	825	825	831
55	1209	1189	1149	1171	1081
61	1350	1327	1300	1319	1345
63	599	592	578	577	590
64	530	533	547	559	499
65	895	963	983	1024	890
66	1553	1575	1590	1610	1547
67	875	913	934	963	878
68	1412	1387	1395	1390	1415
69	1280	1380	1433	1480	1283
70	700	783	792	822	698
73	988	1003	1026	1053	953
74	283	228	210	137	270
75	1005	1142	1207	1273	999
76	1268	1323	1348	1373	1282
77	1006	943	921	897	1005
78	612	578	568	552	616
79	1092	1180	1239	1300	1049
80	1017	1044	1055	1066	1013
81	697	626	607	586	699
82	1187	1128	1130	1123	1140
83	812	878	909	937	810
84	705	704	703	703	705
87	1197	1170	1177	1193	1203
88	958	850	812	762	961
89	1170	1204	1220	1232	1163
90	1131	1120	1131	1135	1132
91	1122	1166	1187	1210	1119
92	963	962	960	960	963
93	1202	1190	1189	1192	1202
94	1428	1474	1497	1522	1426
95	1583	1606	1612	1612	1581
96	1333	1340	1343	1348	1332
97	1593	1628	1645	1663	1588
98	937	912	901	887	935

TABLE XL

OBSERVED STRAIN GAGE DATA

Run Number 7 Date: 30 August 1.16

Beam Span 7 feet Load Position 2½ feet from near support

Reading Number	Load (pounds) 470	2195	3535	4480	505
1	1519	1352	1370	1380	1303
2	1410	1380	1315	1255	1483
3	820	699	632	580	799
4	1030	1071	1068	1121	1011
5	1170	971	872	790	1132
6	810	654	542	451	790
7	1642	1695	1701	1749	1619
8	1361	1185	1072	995	1250
9	938	800	689	410	781
10	772	958	939	1157	940
11	890	700	581		429
12	1303	1198	997	433	868
13	1489	1278	1183	810	1281
14	1670	1458	1355	943	1580
15	1380	1339	1316	1297	1370
16	730	635	580	545	731
17	1306	1513	1321	1389	1508
18	1119	1103	1008	1091	1115
19	920	839	799	762	921
20	770	760	759	754	772
21	1523	1502	1490	1480	1523
22	1410	1302	1240	1182	1410
23	1482	1481	1481	1482	1478
24	847	828	818	810	841
25	1300	1340	1250	1221	1255
26	879	897	905	911	872
27	1438	1353	1315	1282	1420
28	1257	1150	1121	1198	1320
29	1360	1349	1344	1338	1358
30	719	629	582	542	720
31	752	599	486	089	330
32	970	971	941	866	980
33	1327	1280	1332	1408	1451
34	1175	951	820	671	840
35	1470	1351	1291	1101	1302
36	968	966	1019	1103	1078
37	1032	935	882	859	1030
38	910	909	752	698	910
39	1285	1252	1269	1278	1280
40	1540	1470	1432	1401	1538
41	1580	1410	1369	1310	1521
42	1167	1183	1192	1201	1166
43	875	780	717	659	832
44	999	1008	1020	1041	981
45	758	740	720	718	742

TABLE XL (CONT.)

OBSERVED STRAIN GAGE DATA

Run Number 7 Date: 30 August 1946

Beam Span 7 feet Load Position 2½ feet from near support

Reading Number	Load(pounds) 470	2495	3535	4490	505
46	1110	1019	972	942	1150
47	1151	1140	1160	1160	1170
48	867	861	850	865	884
49	671	597	541	500	678
50	871	883	862	860	871
51	1313	1312	1309	1302	1318
52	974	970	971	975	972
53	1020	931	889	849	1021
54	1466	1460	1468	1471	1466
55	951	906	852	792	886
61	1240	1452	1560	1548	1550
63	1415	1368	1335	1196	1304
64	429	540	692	1025	720
65	955	1207	1358	1313	803
66	1073	1157	1181	1255	1114
67	469	442	410	355	423
68	1267	1219	1104	1108	1025
69	673	513	1060	1367	810
70	617	698	758	753	616
73	830	780	755	715	835
74	1116	1080	1077	1052	1122
75	940	1115	1202	1263	950
76	1220	1275	1300	1305	1223
77	930	873	844	803	937
78	513	492	485	462	510
79	1035	1154	1213	1248	1040
80	946	975	990	982	949
81	1563	1501	1466	1422	1570
82	1019	1003	1002	987	1017
83	740	803	840	847	743
84	633	633	633	610	634
87	1072	1050	1050	1037	1073
88	967	866	822	765	972
89	1148	1183	1197	1190	1153
90	1000	1103	1014	1000	1022
91	985	1031	1050	1077	1021
92	780	767	744	749	784
93	1050	1020	1002	987	1020
94	1282	1302	1335	1410	1280
95	570	667	715	882	708
96	1240	1274	1298	1333	1290
97	547	553	553	514	530
98	836	726	663	463	723

TABLE XLI

OBSERVED STRAIN GAGE DATA

Run Number: 8 Date: 30 August 1946

Beam Span 6 feet Load Position 2½ feet from near support

Reading Number	Load(Pounds) 400	[illegible]	[illegible]	[illegible]	[illegible]	520
1	1315	1349	1360	1370	1307	1313
2	1502	1388	1330	1278	1191	1198
3	821	716	660	602	538	613
4	1021	1160	1138	1111	1158	1019
5	1170	971	895	812	736	1140
6	820	651	572	491	421	708
7	606	838	760	709	1119	970
8	1260	1068	971	875	1585	1017
9	899	859	870	479	1085	1327
10	945	1050	1178	1148	[illegible]	[illegible]
11	1411	[illegible]	1115	[illegible]	[illegible]	[illegible]
12	837	780	695	638	579	1328
13	[illegible]	[illegible]	970	97	[illegible]	778
14	[illegible]	[illegible]	1121	1121	1030	872
15	1370	1341	1328	1302	1271	1377
16	736	648	605	561	500	732
17	1308	1310	1318	1321	1332	1306
18	1118	1103	1088	1091	1081	1112
19	829	849	812	778	725	821
20	782	760	755	751	750	781
21	1529	1509	1498	1489	1470	1525
22	1420	1382	1369	1215	1157	1417
23	1479	1480	1480	1479	1479	1476
24	841	825	818	810	799	837
25	1259	1240	1231	1219	1209	1252
26	872	850	838	805	815	870
27	1430	1353	1321	1286	1248	1425
28	1232	1162	1130	1095	1048	1228
29	1357	1348	1340	1332	1321	1357
30	732	632	532	525	498	720
31	1089	1153	1068	1090	1855	2243
32	875	838	809	831	800	768
33	1440	1400	1470	1486	1785	1720
34	850	727	662	532	1301	1501
35	1307	1255	1130	1122	450	829
36	1078	1090	1038	1106	1281	1248
37	1036	945	900	852	782	1128
38	815	819	770	720	681	887
39	1328	1282	1268	1273	1289	1224
40	1340	1477	1442	1410	1398	1338
41	1529	1430	1384	1339	1270	1525
42	1108	1181	1169	1156	1209	1163
43	825	742	700	653	404	704
44	980	1012	1029	1040	1060	950
45	742	730	720	711	710	752

TABLE XLI (CONT.)

OBSERVED STRAIN GAGE DATA

Run Number: 8 Date: 30 August 1946

Beam Span 6 feet Load Position 2½ feet from near support

Reading Number	Load (pounds)					
	490	2560	1470	[illegible]	[illegible]	510
46	1139	1045	1002	[illegible]	911	1126
47	1170	1164	1102	[illegible]	1180	1190
48	863	860	836	851	913	868
49	669	687	677	614	455	670
50	872	866	861	840	831	870
51	1315	1310	1305	1300	1291	1318
52	972	968	960	989	972	971
53	1022	[illegible]	991	990	893	1022
54	1468	1461	1456	1461	1472	1468
55	829	831	832	812	720	829
61	1810	1804	1785	1877	1828	1970
63	1307	1216	1230	1208	957	1090
64	773	791	935	987	1738	1457
65	736	1110	1183	1147	944	294
66	1473	1145	1181	1220	1717	1508
67	400	370	355	347	303	378
68	1224	1172	1150	1105	982	1110
69	892	1113	1220	1337	1103	486
70	1795	1782	1760	1702	1747	1555
73	684	700	700	735	707	836
74	1123	1092	1082	1069	1057	1119
75	965	1032	1102	1208	1353	943
76	1217	1207	1200	1210	1339	1220
77	867	877	850	814	720	838
78	1476	1461	1448	1438	1437	1481
79	1039	1031	1110	1210	1237	1035
80	943	970	982	992	1001	943
81	1563	1530	1475	1413	1410	1566
82	1018	1019	995	975	1005	1013
83	1838	1745	1774	1839	1938	1887
84	1578	1578	1578	1573	1589	1578
87	1071	1052	1052	1032	1052	1068
88	977	985	985	783	732	970
89	1146	1179	1150	1202	1210	1150
90	1030	1017	1018	1014	1027	1027
91	1015	1065	1057	1110	1155	1080
92	774	785	757	749	720	754
93	1020	988	974	960	900	973
94	328	410	445	485	680	484
95	898	781	850	860	1113	895
96	1283	1313	1327	1342	1445	1360
97	530	547	551	558	562	530
98	728	652	687	529	513	490

APPENDIX E

BIBLIOGRAPHY

	Title	Author
1.	Philosophical Magazine, Ser. 5, Vol. 32, 1891	Carus Wilson
2.	Philosophical Transactions, Royal Society, London Ser. A, Vol. 228, 1929	A.E.H.Love
3.	Philosophical Transactions Royal Society, London Ser. A, Vol. 201, 1903, p.63	L.N.G.Filon
4.	Stress in Gun Turrets, Mems #75	Wm. Hovgaard
5.	Handbuch der Experimental Physik, Vo. 4	Krafts
6.	Untersuchen uber das Gleichgewicht des Llastischen Stabes	L. Pochhammer
7.	Transactions Royal Society Edinburgh, Vol, 49, 1914, p. 805	J. Dougall
8.	Theory of Plates and Shells	S. Timoshenko
9.	Theory of Elasticity	S. Timoshenko
10.	Strength of Materials, Part II	S. Timoshenko
11.	Theory of Structures	S. Timoshenko

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Thesis W9 Wright
An investigation of the shear stress distribution in a simply supported I-beam with a concentrated load acting near one end.